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Organization of Research, Development, and Production in the Soviet Computer Industry

Heather Campbell

A report prepared for

UNITED STATES AIR FORCE PROJECT RAND

Rand
SANTA MONICA, CA. 90406

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An examination of Soviet computer research and development; the problems that plague the industry and the ways in which the government and Party have attempted to cope with them; and the constraints, incentives, and feedback mechanisms of the system acquisition process as they operate in a closely controlled, bureaucratic structure. The author describes the origins and characteristics of the Soviet computer industry, traces the attempts of the Party and government to intervene in the industry, and analyzes the effects of this intervention. The main research and design institutes are discussed in terms of each institute's relationship to its governing ministry. More than 25 production facilities are identified and described with respect to age and importance, machines and equipment produced, and the role of each within the general scheme of the Soviet computer industry. The author concludes that the industry's problems are too deep-seated for quick solution; major changes must be made in both the industry and the bureacracy that controls it. Bibliog. (DGS)

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Organization of Research, Development, and Production in the Soviet Computer Industry

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PREFACE

This report is a product of a broad program of research on R&D and Acquisition, sponsored by the Air Force under Project RAND. In assessing alternative acquisition policies, both U.S. and foreign commercial and military acquisition experience has been examined under this program. Some earlier Rand studies have focused on R&D in the Soviet aviation industry[1] and on R&D in the American computer industry. This study considers how complex technological systems with both civilian and military applications are developed in a country other than the United States.

Three aspects of the system acquisition process are illuminated for the policymaker in this study. First, the study presents a brief overview of the organization of the Soviet computer industry from research through development and production, concentrating on some of the major systematic problems. Second, the report examines the attributes of problems that arise when R&D is decoupled from production, and describes ways in which the Soviet government and the Communist Party of the Soviet Union have attempted to cope with them. Third, the study focuses on the constraints, incentives, and feedback mechanisms of the acquisition process as they operate in a particular institutional environment. It shows how the organization of the R&D process affects the outcomes, particularly in the case of innovation of a new technology.

At the outset, it should be made very clear that this study does not attempt to evaluate the technology elements of the Soviet computer industry, and it is not an economic analysis, although an economic analysis might well bear out the hypotheses advanced here. Rather, the study should provide helpful insights into a number of organizational and managerial obstacles to the further development of Soviet computer technology that may be most susceptible to solution, given the present-day organizational constraints.

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[1] A. J. Alexander, *R&D in Soviet Aviation*, R-589-PR, November 1970, and H. Campbell, *Controversy in Soviet R&D: The Airship Case Study*, R-1001-PR, October 1972.

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The study focuses on the development of computer hardware. Since software usually takes a separate development path, and since a large number of Soviet agencies, including many computer customers, have been involved in software development, the author decided to concentrate on the main organizations that research, develop, and produce computer hardware. An additional reason for the hardware limitation is that an earlier Rand report details the work of some of the leading software institutes.[2] Suffice it to say here that lack of adequate software is a major deficiency in the Soviet computer industry.

The report also concentrates on the development of digital computers rather than analog computers, and on general-purpose rather than special-purpose computers. Both analog computers and special-purpose computers (whether digital or analog) have limited uses, and computer scientists usually measure progress in computer technology by the state of the art in general-purpose digital computers.

Computer development in the Eastern European countries is mentioned in this study only insofar as it is part of the total Soviet effort; the R&D processes in those countries, particularly in East Germany, are known to be somewhat different from those in the Soviet Union. East German research and development in the field of computer technology is particularly unlike that of the Soviet Union and could be the possible subject of some very useful follow-on work.

The information provided in this report should give the policymaker better insights into the ability of the Soviet Union to develop modern technology in the civilian sector. Such insights should be useful in evaluating the potential for technology exchange, particularly in the area of computers, between the United States and the Soviet Union. The study should also be useful to Air Force analysts and planners of R&D procurement, and to those interested in the origin of Soviet computers.

The reader may note some inconsistencies in the transliteration of Russian words throughout this study. They arise in the author's

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[2]S. Kassel, *Soviet Cybernetics Research: A Preliminary Study of Organizations and Personalities*, R-909-ARPA, The Rand Corporation, December 1971.

preference for the widely used Library of Congress transliteration system and the concurrent necessity for reproducing, as used, information from sources that incorporated the U.S. Board of Geographic Names system.

Data gathering for the study was completed in June 1974. Problems of transliteration and competing demands on the author's time led to delays in the completion of the manuscript. The work was supported under the Project RAND research project "System Acquisition Policy Studies."

SUMMARY

The types of problems that plague Soviet industry in general are particularly noticeable in the computer industry. Major problems include an R&D lag, a low level of technology and production technique, insufficient production of computers, lack of commonality and compatibility, lack of quality control, incompleteness of the product (particularly software), and a low utilization rate of the end product. A number of economic and organizational characteristics may account for many of the chronic problems of management, which are further complicated by politics and ideology. Particularly troublesome are the economic and organizational disincentives, the fragmented administration of the computer industry, and conflicts within the Soviet bureacracy concerning the introduction of computers.

The computer industry began much later in the Soviet Union than in the United States, where a vigorous start had been made by the 1950s. Neither the business machine industry nor the electronic equipment industry was well developed in the Soviet Union when computers became important. Today, the priority given to the Soviet computer industry seems to be rising rapidly, but the importance of the industry will vary according to its perceived contribution to the country's economy and defense.

The Soviet government has tried to increase the effectiveness of the computer industry through a number of mechanisms: (1) relocation of some of the R&D formerly done in the Academy of Sciences institutes to ministry institutes; (2) establishment of economic and prestige incentives; (3) production control through the ministries; (4) intervention through budget control, particularly through Gosplan; (5) directives to existing government organs, such as the ministries; (6) formation of the State Committee on Science and Technology to be a new coordinating agency, including the field of computers; (7) creation of at least one computer *obedeniia* or production association; (8) direct intervention by agreements with foreign governments to produce an intergovernmental series of computers, namely, the Ryad (ES) line of

computers; (9) importation of foreign computers, and (10) increased centralization of domestic R&D effort in the recently announced tie-in of the ASVT work with the Ryad line of computers.

Early computer development in the Soviet Union spans the years 1948 to 1954. The first Soviet computer, the MESM, was designed in 1948. But it was not until 1953, the year of Stalin's death, that a computer (the Strela) was put into production. During this period, most of the computer R&D was centered in the Academy of Sciences system. The Strela is the only pre-1953 machine known to have been designed by a Soviet government agency. The anticybernetics movement, which began in 1949 and peaked in 1953, seems to have considerably delayed development of the Soviet computer industry. Acknowledgment of some anticybernetics holdouts was noted as late as 1971.

Between 1955 and 1965, computer R&D institutes proliferated, and important new computers were developed. Some of these institutes evolved within the Academy of Sciences system; others were formed under the aegis of the Ministry of the Radio Industry or the Ministry of Instrument Construction, Means of Automation, and Control Systems (Minpribor), which were becoming the major computer-producing ministries. Still others sprang up in less auspicious locations. Later, some of the institutes under the Academy of Sciences were transferred to various ministries.

By 1956, there were as many as 16 separate series of Soviet computers (although most were produced in very small numbers). There was little or no apparent coordination among the research, design, and production functions, nor between the development of hardware and the development of software. The Soviet computer industry also suffered from the low priority assigned to it at that time and from a lack of central direction. The bureaucratic structure of industry and the administration of applied research and development both underwent several reorganizations during this period. Major reforms of the Academy of Sciences system also took place in the late 1950s and early 1960s. In April 1961, Science Councils were created to co-ordinate interdisciplinary research on problems considered to be of prime importance, including cybernetics. Party-government concern with the computer

industry was growing during this period, particularly with regard to its status vis-à-vis Western computer technology.

By 1966, as increasing recognition had been given to the introduction of computer technology and automated control systems into the national economy, the Soviet Communist Party and government began a policy of direct intervention in the computer industry. One of the mechanisms used was the importation of foreign computers, even though the need to develop an effective domestic computer industry was stressed. Another mechanism was the adoption of a resolution specifically aimed at appropriately dividing responsibilities among the various agencies concerned with computers.

In late 1969, the Soviets faced the possibility of being overshadowed in the computer field by some of their own Eastern European neighbors. In December 1969, the Soviet government signed agreements with Bulgaria, Czechoslovakia, the German Democratic Republic, Hungary, and Poland for the development and production of the Ryad (ES) line of computers. Since the ES (unified systems) machines are closely modeled after the IBM/360 system, the Soviets can make use of Western-developed software. They have retained control of development and production of the largest machines in the series. All work done on the ES machines within the Soviet Union is being conducted at facilities under the Ministry of the Radio Industry. Some major production facilities are involved in the work, but the heads of at least two major R&D institutions have publicly disavowed any connection with Ryad.

In 1969, Minpribor announced its own series of computers, the ASVT line, which includes D-models (based on discrete elements) and M-models (based on microelectronic elements). The most powerful ASVT machine, the M-4030 computer, has characteristics that have led to speculation that it may be a link between the ASVT-M series and the Ryad line.

At present, the Soviet computer industry is in a transition phase. Only a small amount of the total production effort is going to third-generation machines resembling those common in Western countries; many second-generation machines are still being produced. The Soviet government is attempting to centralize the industry through the Ryad and ASVT efforts, but whether the plan will be successful is open to question.

The Soviet computer industry is fragmented among the Academy of Sciences system, the ministries, and the computer plants, themselves subordinate to one of the ministries. Eleven of the thirteen research and design organizations that have worked on computer hardware are under the control of the Academy of Sciences system, the Ministry of the Radio Industry, and the Ministry of Instrument Construction, Means of Automation, and Control Systems (Minpribor). Two others, not under the jurisdiction of the Academy or the two major ministries, are the Laboratory of Electromodeling (LEM) of the All-Union Institute of Scientific and Technical Information (VINITI) and the Elektronika Institute in Kiev. The Soviet computer industry is also widely dispersed geographically, from Leningrad in the north to Baku in the south, and from Brest in the west to Novosibirsk and Tomsk in the east. (See map on p. 92.) Much of the computer hardware is produced in the Russian Soviet Federated Socialist Republic, but significant work is also being done in the Belorussian, Ukrainian, Armenian, Lithuanian, and Georgian Soviet Socialist Republics.

The roles of the research institutes seem to vary widely. Some concentrate on research, others on design, and some do both research and design. The responsibilities of the design bureaus appear to vary according to the organization to which they are attached. In general, design bureaus subordinate to strong research institutes tend to function at a low level of design, perhaps preparing the already developed computer for production.

Soviet computer R&D has been under the leadership of a number of well-known computer specialists, such as Academician S. A. Lebedev, designer of the Soviet Union's first electronic computer, the MESM, as well as the BESM-1, the first large Soviet computer. Lebedev collaborated with M. K. Sulim in the design of another machine, the M-20. Other important designers and developers include Yu. Ya. Basilevskii, of the Institute of Mechanics and Instrument Design of the Ministry of the Radio Industry, designer of the Ural-1; B. I. Rameev of the Penza SAM Plant, who worked with Basilevskii in designing the Ural-1, headed the product group at Penza that designed the Ural-2 and the Ural-4; L. N. Korolev, a designer under Lebedev; N. A. Mel'nikov,

Lebedev's second-in-command; V. M. Glushkov, head of the Institute of Cybernetics, developer of a number of computers, including the Mir and Iskra; S. N. Mergelyan, director of the Scientific Research Institute of Mathematical Machines, best known for its Nairi and Razdan series; I. S. Bruk, of the Institute of Electronic Control Computers, developers of some of the earliest small and medium general-purpose digital machines, the M-1, M-2, and M-3; V. Koval', Chief Engineer of the Sigma Association, developers of the M-5000 process control computer and of the Ruta-110 information-processing system; and V. V. Przhiyalkovskii, head of the Minsk Ordzhonikidze Computer Factory, developers of the Minsk line, one of the most widely used series of computers in the USSR.

Most Soviet computer production facilities seem to be under the jurisdiction of either the Ministry of the Radio Industry or the Ministry of Instrument Construction, Means of Automation, and Control Systems (Minpribor). Whether some small production facilities still remain under one of the divisions of the USSR Academy of Sciences is uncertain. At least one, the Minsk Ordzhonikidze Computer Factory, is believed to have been under the Belorussian Academy of Sciences before being taken over by the Ministry of the Radio Industry.

At least six Soviet computer production facilities operate under the jurisdiction of the Ministry of the Radio Industry: the Brest Electromechanical Plant, the Minsk Ordzhonikidze Computer Factory, the Moscow Calculating and Analytical Machines (SAM) Plant, the Penza Calculating and Analytical Machines (SAM) Plant, the Elektron Computer Plant in Erevan, and the Baku Radio Factory in Azerbaijan. Three of these facilities are among the oldest and most important in the Soviet Union: The Minsk Ordzhonikidze Computer Factory, designer and builder of the Minsk line of computers, the most widely distributed computers in the national economy of the Soviet Union; the Moscow Calculating and Analytical Machines (SAM) Plant, producers of the first industrially manufactured computer, the Strela, and the BESM-6, the best-known scientific computer; and the Penza Calculating and Analytical Machines (SAM) Plant, home of the Ural line, and current producers of the ES-1050 computer, one of the two Ryad machines to be manufactured exclusively by the Soviet Union.

Production facilities under the control of Minpribor include the Kiev Electronic Computer and Control Machines (VUM) Plant; the Leningrad Electromechanical Plant; the Kursk Calculating Machines Factory; the Orlov Control Computer Plant; the Ryazan' Calculating-Analytical Machines Plant; the Smolensk Small Computer Plant; the Severondonetsk Computer Factory; the Tomsk Mathematical Machines Plant; and seven plants under the Sigma Association of Calculating and Organizational Equipment Enterprises. Of these, probably the best known is the Kiev Electronic Computer and Control Machines (VUM) Plant, producers of the Dnepr system (the first computer system in the USSR for large-scale automation of industrial enterprises), the Mir-1 and Mir-2, and Minpribor's newest computer series, the ASVT (Modular System for Computer Hardware).

The Iskra series, the most important type of electronic keyboard calculators, is produced by several Minpribor facilities: The Kursk Calculating Machines ("Schetmash") Factory has produced six Iskra models (Iskra, Iskra-12, Iskra-12M, Iskra-22, Iskra-112P, and Iskra-122). The Orlov Control Computer Plant has produced the Iskra-11 and the more advanced Iskra-111. The Iskra-23, used for engineering and economic calculations, is serially produced by the Ryazan' Calculating-Analytical Machines (SAM) Plant, and the Iskra-110 table-model computer is produced by the Smolensk Small Computer Plant.

The Sigma Association of Calculating and Organizational Equipment Enterprises in Lithuania comprises three design bureaus and seven plants. The most important appears to be the Vilnius Calculating Machines Plant, established in 1952. This plant is involved in the development of the Ruta computer complex to mechanize and automate production administration, as well as in the production of the ATE-80 electronic printer for economic data processing and the M-5000 third-generation computer intended for "the most complex economic calculations." The remaining six appear to be specialized plants whose products range from unitized perforators to electronic equipment.

Besides the plants under the Ministry of the Radio Industry and Minpribor, there are a number of other computer factories of unknown organizational subordination. One of them, the Tbilisi Experimental Plant of Control Computers, produces the Gelati-3 and Gelati-5 keyboard computers used for statistical and accounting calculations.

The present and future of the Soviet computer industry will be greatly affected by the past. The numerous Party directives and reorganizations have not changed the nature of the sector the Soviet Party and government must work with (or against). Unless such difficulties as rigid bureaucratic boundaries, backward managerial practices, and weak customer demand are remedied, previous steps taken by the Soviet Communist Party and government will not substantially improve the situation. The Soviets might look to the German Democratic Republic to help fill in the gaps if they were to find it in their interest to promote an Eastern European computer industry rather than a Soviet computer industry.

ACKNOWLEDGMENTS

I want to thank Rand colleagues Mario Juncosa, Arthur Alexander, Nancy Nimitz, and John Despres for their many helpful suggestions. Mario Juncosa acted as technical advisor as well as serving as concerned reviewer. Arthur Alexander supplied encouragement and guidance as the project leader. Nancy Nimitz provided valuable background on the Soviet industrial bureaucracy. I also appreciate the efforts of John Despres as a reviewer.

Other Rand researchers who gave me technical advice and general information on the international computer industry include Willis Ware, Rein Turn, and Alvin Harman. I am particularly indebted to Malcolm Davis, who furnished the information on which Fig. 2 is based.

The help of Wade Holland, editor of the *Soviet Cybernetics Review*, is greatly appreciated. Not only were my discussions with him of considerable value, but the material published in the *Soviet Cybernetics Review* made this study possible. The discontinuation of the *Review* is a great loss to those interested in Soviet cybernetics.

I especially want to thank Patricia Hays of the *Soviet Cybernetics Review* staff for providing me with much of the original Russian material used in the *Review*.

CONTENTS

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FIGURES

TABLES

A GLOSSARY OF SOME RUSSIAN TERMS AND ABBREVIATIONS USED IN THIS REPORT

ASVT	Modular System of Computer Hardware (line of computers)
ASVT-D	Modular System of Computer Hardware--discrete elements
ASVT-M	Modular System of Computer Hardware--microelectronics
ES	Unified System (line of computers; same as Ryad, below)
CPSU	Communist Party of the Soviet Union
CEMA	Council of Mutual Economic Aid
Gosbank	State Bank
Gosplan	State Planning Agency
Stroibank	Bank for the Financing of Capital Investments
LEM	Laboratory of Electromodeling
NOT	scientific organization of labor (Soviet jargon for "scientific management")
Minpribor	Ministry of Instrument Construction, Means of Automation, and Control Systems (English acronym, MICMACS)
NIISchetmash	Scientific Research Institute of Calculating Machine Construction
NIIUVM	Scientific Research Institute of Control Computers
obedeniia	production associations
Ryad	"Series" (line of computers; see ES, above)
Schetmash	Calculating Machines
SAM	Calculating and Analytical Machines
sovnarhozy	regional economic councils
Tochelektropribor	Precision Electrical Appiances
VEM, EVM	Electronic Computers
VNIIEM	All-Union Scientific Research Institute of Electromechanics
VINITI	All-Union Institute of Scientific and Technical Information
VUM	Electronic Computing and Control Machines

I. INTRODUCTION

Gathering useful information on the organization and outcomes of the Soviet computer industry is more difficult than it would seem at first glance. Soviet computer scientists are even more secretive than their American counterparts about their work and their products. Announcements of computers very often appear without identification of either the manufacturing ministry or the R&D institute responsible for the product. Press or other public reports are also vague as to the date on which production began, the method of production (serial or hand-tooled), the plant or plants involved, and so on. Specific numbers, whether production figures, utilization rates, or investment dollars, are either very scarce or lacking altogether. Some of the articles in the Soviet press discuss difficulties, but do not pinpoint them with concrete data. Published data often turn out to be imprecise, unreliable, or unverifiable. In some cases, information appears to be contradictory; in others, extrapolations must be made on scanty evidence.

As with many other Soviet civilian industries, computer R&D is not concentrated under a single Soviet government agency. It is instead dispersed over several industrial ministries, the State Committee on Science and Technology of the Council of Ministers of the USSR, and the Intergovernmental Commission for Computer Techniques. Some of the major computer research institutes are under the jurisdiction of the USSR Academy of Sciences and the Republic Academies of Sciences. Several industrial ministries also conduct computer R&D, the most important being the Ministry of the Radio Industry and the Ministry of Instrument Construction, Means of Automation, and Control Systems (Minpribor). However, the Ministry of the Electronics Industry also does some computer R&D. The State Committee on Science and Technology primarily acts as a coordinating agency, although some research is conducted under its supervision.

The Intergovernmental Commission for Computer Techniques and its Council of Designers are responsible for R&D decisionmaking on the Ryad

line of computers being developed jointly by the Soviet Union with several Eastern European countries.[1] The Soviet contribution to this effort is being implemented under the Ministry of the Radio Industry.

This dispersion of R&D decisionmaking is the result of the fragmentary nature of early computer research, and subsequent attempts by the Soviet government and the Communist Party to control developments in the industry.

The origins and most important characteristics of the Soviet computer industry are identified in Section II.

Section III traces the attempts of the Soviet Communist Party and government to intervene in the computer industry, and analyzes the effects of this intervention.

Section IV focuses on the work and characteristics of the research, development, and design organizations at the institute level.

Section V relates the Soviet computer production facilities to the research institutes whose products they manufacture.

Section VI presents the author's summary conclusions about the state of the Soviet computer industry and some of its major systemic problems.

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[1]More recently the Ryad ("series" in Russian) line of computers has been designated by the term "ES" ("Unified System" in Russian).

II. CHARACTERISTICS OF THE SOVIET COMPUTER INDUSTRY

It would appear from the recent directives of the Soviet government that the computer industry has at last attained, if not top priority, at least a status that is rising rapidly.[1] However, the computer equipment that the Soviets have been able to produce so far appears to lag Western equipment by a significant margin, and many customer complaints about inadequate or unreliable equipment still appear in the Soviet press. What accounts for this seemingly paradoxical situation? The explanations lie somewhere in the long process from basic research on computer technology to customer use.

Western experts have long recognized the excellence of Soviet research in basic science and mathematics.[2] Yet it is apparent that the same tradition of excellence has not been continued in most areas of applied science. One economist states:

> Except perhaps for military and related fields there probably is no "knowledge" gap of any significance between the USSR and the West. The Soviet Union not only has long had a large domestic research establishment for the development of scientific and technical knowledge, but also has made large-scale and concerted efforts to acquire world know-how through literature and trade. Despite these considerable efforts over many years, however, the Soviet Union clearly has not succeeded in matching the level of applied industrial technology of the U.S. and Western Europe. On this point Soviet economists and government officials seem to be unanimous, for the press is replete with citations of Soviet technological backwardness in area after area of the economy.[3]

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[1] See the discussion of the priority of the Soviet computer industry in Section III.

[2] See Richard W. Judy, "The Case of Computer Technology," in Stanislaw Wasowski (ed.), *East-West Trade and the Technology Gap: A Political and Economic Appraisal* (New York: Praeger Publishers, 1970), pp. 66-67.

[3] Gertrude Schroeder, "The Economic Reform As a Spur to Technological Progress in the USSR," *Jahrbuch der Wirtschaft Ost Europas*, Vol. II (Munich: Gunter Ol Zag, Verlag, 1971).

The problems that plague Soviet industry in general are both serious and visible in the computer industry because of its potential role in increasing the technological development of other industries and its great importance to the operation of the Soviet economy as a whole. Many of the problem areas can be easily identified from accounts of Western visitors who have viewed Soviet computer equipment and from criticisms published in the Soviet press. The circumstances contributing to these problem areas are more difficult to perceive and analyze.

Some of the problems and characteristics of the computer industry can be found in many Soviet industries, which operate in an environment of economic disincentives to success. Others characterize any extremely complex and sophisticated new technology that has grown up within a rigid, pre-existing bureaucratic structure, without the careful, advance planning so necessary to an emerging new industry. Still others are peculiar to the industry itself. For example, the computer industry requires a constantly advancing technology, which intensifies the problems found in other industries that are not required to advance so rapidly.

Major problem areas include an R&D lag, low-level technology, low-level production techniques, insufficient numbers of computers being produced, a lack of commonality and compatibility, a lack of quality control, an incomplete product, and a low utilization rate of the end product. These will be discussed below, followed by an analysis of the economic and organizational characteristics that may account for many of the problem areas, such as, for example, the planning and managerial context within which the Soviet computer industry operates, the vertical and horizontal fragmentation of its administration, and the conflict within the Soviet bureaucracy about the introduction of computers.

MAJOR PROBLEM AREAS IN THE SOVIET COMPUTER INDUSTRY

One major problem that occurs in the Soviet computer industry, and in many other Soviet industries, is the lag between R&D for a particular product and the product's entrance into the economy. This problem has been noted by a prominent Soviet mathematician working in the computer field, Academician G. I. Marchuk, head of the Novosibirsk Science City's

computing center and a Vice President of the Siberian Division of the USSR Academy of Sciences. Marchuk has estimated the lag to be 8 to 10 years. He also has indicated that only about 50 to 60 percent of the scientific research has been completed by the time results are translated into practical applications.[4] Another Soviet computer specialist, V. M. Glushkov, Director of the Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR, has noted that a team of specialists usually spends 3 to 4 years completing just the design phase of a computer.[5] This situation alone greatly handicaps the Soviets in their attempt to keep up with a fast-moving international industry such as the computer industry.

In general, the level of Soviet computer technology is behind that of the West by about 4 to 5 years for hardware, and 8 to 10 years for software. The estimates vary, depending on the particular aspect of computer technology being discussed. Many early (and primitive by today's standards) Soviet machines are still in use. Besides reflecting the general Soviet attitude about not throwing away obsolete equipment, this situation may also be taken as an indication that the Soviets are not innovating and producing new computers as fast as the West. One Soviet critic of the computer industry wrote that Soviet computer designers "follow the path of small-scale modernization," not making qualitative strides in the field, but only improving what already exists.[6] The closest the Soviets have come to approximating Western computers is the Ryad (ES) line of computers, patterned after the IBM 360 system, and the ASVT series, some models of which are

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[4]"10-Year R&D Lag," *Soviet Cybernetics Review*, Vol. 2, No. 5, September 1972, pp. 11, 21.

[5]V. M. Glushkov, "Sopernik konstruktora" ["The Designer's Rival"], *Nedelya*, No. 20, July 21, 1968, p. 6; translated in *Soviet Cybernetics: Recent News Items*, No. 21, September 1968, p. 19.

[6]V. Golovachev, "Rozhdaetsya Gerkules chto sderzhivaet razvitie elektronnoj vychislitel'noj tekhniki v strane" ["A Hercules Is Born That Is Retarding the Development of Electronic Computer Technology in the Country"], *Trud* [*Labor*], March 19, 1967, p. 3; translated in *Soviet Cybernetics: Recent News Items*, No. 5, June 1967, p. 75.

third-generation machines.[7] However, the production of these computers has lagged far behind schedule, and there is some doubt that they will perform as advertised.[8]

Production techniques in the Soviet computer industry vary considerably, but are generally less advanced than in the United States. The most highly automated plants appear to be those producing the Ryad and ASVT computers. For example, the Minsk Ordzhonikidze Computer Factory is said to have developed the means for mechanizing the assembly, wiring, and debugging of computers, as well as the electroplating, painting of parts, and other processes.[9] The only 1973 State Prize awarded in the field of cybernetics, computer science, and automation went to a project entitled, "Development of Methods and Establishment of Hardware for an Integrated Mechanized and Automated Technological Process for Mass Production of Computer Memory Storage Devices."[10] The nomination of this project indicated that it was connected with the assembly of cores for the memory of the ES-1020 manufactured by the Minsk Ordzhonikidze Computer Factory.[11] The computer- and components-producing enterprises

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[7]Generations of computers are generally distinguished by the nature of their components. Roughly speaking, the generations are as follows: *first generation*--vacuum tubes in circuits; *second generation*--transistors in place of vacuum tubes; *third generation*--integrated circuitry, based on microcircuitry or microelectronics; *fourth-generation*--large-scale integrated circuitry (LSI). Alternative ways of classifying these generations may be formulated by classifying their software and/or architecture, i.e., by the sophistication of the languages used and by the degree of modularity of the architecture. It is not unusual for a computer to be of more than one generation. The American CDC 7600, for example, is based on discrete transitors (second generation) but is considered a third-generation machine because of its unique architecture, which gives it a capability for high speed and multiple parallel processing.

[8]See, for example, Wade B. Holland, "Ryad Arrives--And So Does the Party," *Soviet Cybernetics Review*, Vol. 2, No. 3, May 1972, pp. 7-12; and Wade B. Holland, "Unwrapping the ES Computers," *Soviet Cybernetics Review*, Vol. 3, No. 5, September 1973, pp. 7-22.

[9]"Postavleny na konvejery" ["On the Assembly Line"], *Izvestiia*, April 15, 1972, p. 6.

[10]"1973 State Prizes," *Soviet Cybernetics Review*, Vol. 3, No. 6, November/December 1973, pp. 5-6.

[11]S. Lebedev and V. Petrov, "Konvejer mashinnoi pamiati" ["Computer Memory Conveyor"], *Izvestiia*, August 19, 1972, p. 5.

of the Sigma Association, the manufacturers of the M-5000, have also invested a significant amount of resources in organizing and automating production.[12] At the other extreme, low-level production techniques are said to greatly hinder the manufacture of control computers.[13] Most of the automation of Soviet computer plants has taken place only since the mid-1960s.

The number of machines produced by the industry is also far from adequate for the needs of a major industrial country. In 1970, the Soviet Union was estimated to have between 4200 (by the Diebold Group, Inc.) and 5500 (by the International Data Corporation) computers,[14] whereas the United States was estimated to have between 62,000 (by the International Data Corporation) and 70,000 (by the Diebold Group, Inc.). The current (ninth) Five-Year Plan (1971-1975) calls for 12,000 to 15,000 third-generation (Minsk-32, Nairi-3, and M-4000) computers by 1975, and 33,000 units of the Ryad line during the same period. It is difficult to understand how the Soviets will achieve their goals, since the 1973 Soviet computer production has been estimated at only 1000 systems.[15]

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[12]"Cost Accounting Successful in Sigma Association of Calculating and Organizational Equipment Enterprises," *USSR Industrial Development, Electronics and Precision Equipment*, No. 26, JPRS 41,670 (Joint Publications Research Service, TT: 67-32302), July 1, 1967, pp. 1-18. (See also A. R. Kudukias, "Calculator Plant Automating Production; translation of excerpts in *Soviet Cybernetics Review*, Vol. 3, No. 5, September 1973, pp. 76-77.)

[13]G. A. Gegeshidze and A. M. Shapiro, "Low Output of Control Computers Documented," translation of excerpts from "Prospects of Technical Rearming of the Branch Producing Special-Purpose Computers and Numerical Program-Control Devices" ["O perspektivakh tekhnicheskogo perevooruzheniya otrasli po proizvodstvu spetsializirovanny kh EVM i ustrojstv chislovogo programmnogo upravleniya"], *Instruments and Control Systems* [*Pribory i sistemy upravleniya*], No. 3, 1972, p. 3, in *Soviet Cybernetics Review*, Vol. 2, No. 6, November 1972, pp. 47-49.

[14]The figures were cited in "Survey of CEMA Computer Production and Use Presented," excerpts from an article by P. Hanak and I. Lipovecz [*sic*] in *Magyarorszag* (Budapest), No. 53, December 31, 1972, pp. 10-11; translated in *Translations on Eastern Europe: Economic and Industrial Affairs*, No. 829, JPRS 58,165, February 6, 1973, pp. 1-4.

[15]Jack Robertson, "Build 1000 Systems in Russia in '73: CIA," *Electronic News*, September 17, 1973, p. 32.

There is a general lack of commonality and compatibility even within families of computers. Mass production of computers using sophisticated techniques is not generally practiced in the Soviet Union, and during series production, changes are sometimes made as bugs are discovered, or substitutions are made for materials in short supply. A more serious form of incompatibility may occur when machines in the same series are developed by different research institutes, designed by different design bureaus, and produced in various factories that don't necessarily have the same production standards. The likelihood of this happening will become more apparent when the fragmentation of the Soviet computer industry is discussed below.

An example of this lack of compatibility can be found even in one of the most up-to-date series of Soviet machines. In the ASVT-D series, for instance, "the instruction repertoire of the M-1000 does not conform to the accepted standard for [the] ASVT [line]."[16] The peripheral devices of the M-1000, M-2000, and M-3000 are also not compatible with each other nor do they conform to general ASVT standards. It is interesting to note that the M-2000 and M-3000 were designed by the Severodonetsk Scientific Research Institute of Control Computers and produced by the Severodonetsk Computer Factory, but that the M-1000 was designed by the Tbilisi Scientific Research Institute of Instrument Construction and Means of Automation and various other unnamed institutes of Minpribor, and has been produced by two experimental plants in Tbilisi.[17]

Another important problem area is that of reliability, identified as "Problem Number One" in a book published by "Znanie" in Moscow under that title. According to the author, "Approximately 70-80% of all failures in technical devices and instruments are [said to be] due to shortcomings in design and manufacture, and only 20-30% are due to

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[16] Wade B. Holland, "Soviet Computing, 1969: A Leap into the Third Generation?" *Soviet Cybernetics Review*, Vol. 3, No. 7, July 1969, p. 14.

[17] The Tbilisi Experimental Plant of Control Computers and the Experimental Plant of the Tbilisi Scientific Research Institute of Instrument Construction and Means of Automation.

improper use."[18] In the past, there has been little effort expended on quality control in production. In most cases, the plant that produced the machine did not even acknowledge a responsibility for the reliability of its product, let alone any other services to the customer. More attention is now being paid to this problem, but there are indications that it has not yet been solved. The Minsk Ordzhonikidze Computer Factory, for example, has instituted a complex quality control system offering financial incentives to workers to maintain high standards. As a result, it is claimed, the Minsk-32 was awarded a State Mark of Quality.[19] However, excessive downtimes have been reported for other machines, including the BESM, Stvela, and Ural, all important computers.[20]

Failure to provide the customer with a complete computer package, beyond the necessary hardware, is a particularly aggravating problem. Customers have complained about the lack of adequate software, the lack of the necessary peripherals, and the failure to provide for proper installation and adequate maintenance of computers. Such complaints involve not only small computers, but also the major ones essential to the functioning of the Soviet economy, such as the third-generation Minsk-32, the Ural-14, and the Ural-11.[21] Another deficiency is the lack of trained computer personnel to serve the customer.

The problem of software is particularly critical in the Soviet computer industry. For many years the principal manufacturing ministries made little effort to provide algorithms and sets of standard

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[18] "Reliability: Problem Number One," *Soviet Cybernetics: Recent News Items*, No. 7, August 1967, p.3.

[19] A. A. Reut, "Quality Control Increases Minsk Outputs," *Soviet Cybernetics Review*, Vol. 2, No. 6, November 1972, pp. 37-39; "Istoki bezuprechnogo kachestva" ["Basis for Faultless Quality"], *Ekonomicheskaya gazeta*, No. 21, 1972, p. 6.

[20] See "Poor Reliability of BESM, Strela, and Ural Computers," *Soviet Cybernetics: Recent News Items*, No. 5, June 1967, p. 4.

[21] See "V tret' sily: pochemu nizka effektivnost' ispol'zovaniia EVM" ["At One-Third Speed: Why Computer Efficiency Is Low"], *Izvestiia*, June 14, 1973, p. 3; and Wade B. Holland, "Computer Users Catalog Their Problems," *Soviet Cybernetics Review*, Vol. 2, No. 4, July 1972, pp. 10-17.

programs for their products. The failure of IBM in 1964 to provide software for the 360 series until more than 2 years after the first machine was sold has been cited in a Soviet article as "evidence of the fact that poor software brings to nothing all the engineering virtues of a machine."[22]

Many of the problems discussed above are reflected in the generally low utilization rate of Soviet computers. Utilization rates in some cases are actually said to be declining.[23] Unreliable machines, inadequate software, no provision for installation, repair, or maintenance, and the users' reluctance to share computers undoubtedly all interact to produce this situation. Also, many organizations have acquired machines "without a sufficient basis for doing so,"[24] and are not adequately prepared for their effective application.

All of these problem areas are not only apparent to Western experts, but have been acknowledged by the Soviets themselves. It is important to keep in mind, however, that these problems are not isolated but interrelated, and that their origins lie in a number of characteristics of the Soviet computer industry, including the planning and managerial context in which computer development takes place, the fragmentation of the industry, and the conflict among Soviet bureaucrats over the use of its end product. These will be discussed below.

PLANNING AND MANAGEMENT OF R&D AND PRODUCTION

The character of Soviet planning and management of R&D and production accounts for many of the problems noted above. Soviet management practices evolved not only out of the ideological tenets of a Marxist state, but were also inherited from the managerial habits of prerevolutionary Russia. Thus, they differ markedly from those of other countries, even other socialist states, such as East Germany, for example.

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[22] O. Aven, "EVM pred'yavlyaet schet" ["The Computer Gives an Accounting"], *Pravda*, July 1, 1967, p. 2; translated in *Soviet Cybernetics: Recent News Items*, No. 8, September 1967, p. 12.

[23] "Ekonomicheskaya otsenka ekspluatatsii EVM" ["An Economic Appraisal of Computer Utilization"], *Planovoe khoziaistvo*, No. 1, January 1974, pp. 61-66.

[24] Aven, op. cit.

There is also a striking difference in their effectiveness.[25]

At the highest level of planning, the way in which the Soviets distribute their R&D funds may give some indication as to why the computer industry does not advance as rapidly as one would expect. In the 1960s, only 28 percent of the total Soviet R&D expenditures went to development, but 60 percent went to applied research and 12 percent to basic research. The current (ninth) Five-Year Plan (1971-1975) was expected to place more emphasis on development and less on research, but it is a little early to tell whether this goal has been accomplished.[26] This means that very little of the total Soviet R&D effort is translated into consumer products. In the United States, the distribution pattern of R&D funds is reversed. During the 1960s, 62 percent of the total U.S. R&D expenditures went to development, 23 percent to applied research, and 15 percent to basic research.[27]

At the ministerial level, there are bureaucratic impediments to the innovation of new technology, both in the computer industry and in other Soviet industries as well. Under the existing ministerial structure, ministers tend to build empires unto themselves. While usually reluctant to take on new responsibilities that do not appear to have clear-cut economic or political payoffs, they resist all attempts to remove any significant function from their control. Usually they don't respond well to the needs of other ministries, whose interests run, at best, a poor second to their own needs and priorities. Cooperation across ministerial lines is, therefore, very difficult to achieve.

The case of the VNIIEM-3 serves as an example. The VNIIEM-3 computer was developed by the All-Union Scientific Research Institute of Electromechanics, whose initials it bears. This Institute falls under the jurisdiction of the Ministry of the Electronics Industry. Although

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[25] For detailed information on this subject, see David Granick, *Industrial Management in Four Developed Countries: France, Britain, United States, and Russia.* (Cambridge, Mass.: The M.I.T. Press, 1972.)

[26] Ronald Amann, "Soviet Research in the Seventies" ["La Recherche Soviétique des Années 70"], *La Recherche*, No. 29, December 1972, pp. 1027-1034.

[27] Granick, op. cit.

the VNIIEM-3 was considered a well-designed machine, the Ministry of Instrument Construction, Means of Automation, and Control Systems, (Minpribor) did not want to produce it because similar machines were already in production. According to a Soviet newspaper article, "neither Gosplan USSR nor the Committee on Science and Technology has been able to crack the stubborn opposition of the Ministries on many of these questions."[28]

Even new technology within a single ministry has to compete against all its other technologies for attention. Computer technology is only one of a number of areas of concern to each of the many ministries involved in the production of hardware, software, peripherals, or components. A Soviet source emphasizes that "A minister has the right to redistribute funds as he sees fit. And since each minister is responsible for his own field, he will first skimp on funds for the development of computer techniques."[29]

At the level of the enterprise, the managerial system becomes a critical factor in the performance of the Soviet computer industry. It is at this level that the career-advancement patterns of enterprise managers interact with the Soviet reward system to produce extreme suboptimizing managerial behavior. In the words of David Granick, an American expert on Soviet managerial problems, "Soviet enterprise managers pursue the interests of their individual enterprises rather than that of the larger organization of which the enterprise is a part."[30] The same might be said of other organizations at all levels of the Soviet economy, including research institutes and even ministries, where similar problems arise as a result of comparable behavior. Granick summarizes the suboptimization problem in specific terms that clearly reveal the depth of this problem area:

> The suboptimizing problem takes a wide variety of forms: misleading data and opinion transmitted to higher authorities in the effort to obtain a lower enterprise plan than would

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[28]Golovachev, op. cit.

[29]Ibid., p. 76.

[30]Granick, op. cit., p. 50.

> otherwise be forthcoming; the slighting of quality in order to reach a higher measured output; the production of undesired proportions of different types of products so as to achieve output and profit targets under conditions of fixed prices that are only weakly related to demand. Investment funds are demanded by all organizations, and many projects are begun with what turns out to be inadequate funding in the justified expectation that more funds will later be added by the state in order to avoid scrapping the project; as a result, investment programs have taken unconscionable periods to complete. Managers have strongly and successfully resisted the starting up of new products in their plants, with the effect that Soviet industry has been consistently slow in adopting product innovations.[31]

This suboptimizing behavior on the part of managers has been fostered by the Soviet industrial bonus system, which is quite different from that in other countries: (1) It includes "all professional and managerial personnel." (2) "The proportion of total earnings which is paid through bonuses is quite high." (3) "Bonuses are heavily linked to specified performance indices of the enterprise or of its subunits, rather than being paid either automatically (as a delayed salary payment) or on the basis of the judgment of superiors." (4) "Bonus payments do in fact appear to vary sharply as a percentage of base salary for given individuals, and major movements downward as well as upward are commonly observed."[32] Clearly, this unique system for rewarding managerial performance acts as a strong deterrent to innovation and encourages suboptimizing behavior on the part of enterprise managers. Career advancement for enterprise managers has been slow and limited since World War II and therefore offers only a weak economic incentive to managerial personnel. The bonus system, on the other hand, is quite a strong economic inducement, affecting managerial behavior in certain limited but not altogether desirable directions.[33] Managerial career patterns in the Soviet Union, unlike those in the United States, do not include much "change of function or movement back and forth between organizational levels" which might socialize managers "to the

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[31] Ibid., p. 51

[32] Ibid., p. 277.

[33] Ibid., pp. 53-54.

need for cooperation with functions outside of the enterprise (such as research and development) or even with higher organizations."[34] Thus the effect of slow career advancement and a strong bonus system is not mitigated by career patterns as it might be in other industrialized countries.

These same economic disincentives seem to be present in other Soviet industries. Generally speaking, bonuses for good research and development are routine and are expected regardless of the quality or value of output. Further, the wage structure of scientific workers is such that workers in research institutes are paid higher wages than those in scientific centers attached to enterprises. This means that scientific laboratories located in plants often lose their better talent to research institutes.[35]

The bonuses for production depend on output and are related to the fulfillment of various indicators. The value of bonuses specifically earmarked for innovation of new technology or products outweighs, by about 10 to 1, the value of bonuses for production. It would seem, therefore, that researchers and designers do not have any special incentive to turn out up-to-date products; in fact, manufacturers are encouraged to continue to produce obsolete products, since current production counts much more than investment in new products, whether it is accomplished through retooling or expansion of facilities. In the computer industry, these disincentives to innovation and the concomitant risk-taking are especially defeating.

That the bonus system greatly affects the Soviet computer industry is clear from complaints published about its application in the Soviet press. One complaint stated that the development rate of new computer equipment was impeded within the Sigma Association because the bonuses given to workers in its research institutes were awarded on a different basis from those given to workers in its production enterprises.[36] Although this article did not specifically state on

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[34] Ibid.

[35] "Nauchnyi tsekh zavoda" ["Scientific Shop of the Factory"], *Pravda*, April 13, 1967, p. 1.

[36] M. Shimanskij and N. Novikov, "Problem-Plagued Ryad Machine Announced," *Soviet Cybernetics Review*, Vol. 2, No. 3, May 1972, p. 16.

what basis the bonuses were awarded, in the past they have been awarded to research workers more or less automatically, but they have been given to enterprise workers on the basis of their productivity.

To complicate the problem of motivating good R&D, incentives are applied inconsistently, even in the more homogeneous Soviet institutions. For example, the following complaint appeared:

> Several institutes participated in the development of the ES-1020 computer. What incentives were given to its developers? This was handled differently even in the institutes within a single branch. No one can explain the reason for this. One thing is obvious: some institutes that produced inferior parts received greater rewards than those that did high-caliber work.[37]

At the level of the user, in the computer industry, as in most other Soviet industries, customer demand is dispersed. In the absence of a market system to aggregate it into a direct, powerful influence on the producer, and indirectly on the developer, customer demand remains a weak and uninfluential force on R&D and the production system. Hence, what the customer needs very often does not get produced, and obsolete or inadequate products are frequently substituted. Recognizing the great potential influence of concerted user demand, V. M. Glushkov has recommended the establishment of a governmental department specifically to serve "the function of general customer of computers and automated systems for the needs of the economy."[38]

The net effect of economic disincentives, bureaucratic impediments, and weak dispersed customer demand is the paradox that we see: an industry, viewed as high priority by the Soviet political and computer leadership, suffering from lack of mechanisms that would make economic investment in it pay off.

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[37]"Cost Accounting Successful in Sigma Association of Calculating and Organizational Equipment Enterprises," op. cit., p. 9. See also Section IV in this report for further elaboration of this problem.

[38]V. M. Glushkov, "ASU: sniat' vedomstvennye bar'ery" ["ASU: To Remove Bureaucratic Barriers"], *Izvestiia*, March 8, 1974, p. 2.

FRAGMENTATION OF THE SOVIET COMPUTER INDUSTRY

The problems characteristic of most Soviet industries are magnified when a particular industry is based on a relatively new and very complex technology evolving within an existing bureaucratic structure. Basic to the translation of a given technology into an industry is continuity--from R&D research to applied research to design to production. It is not necessary that all of these functions be performed by the same organizations; indeed, many times they are not. However, they must be viewed, not as independent activities, but as part of a process in which the product is the ultimate goal.

The highly fragmented nature of the Soviet computer industry does not promote this view of a continuous process; in fact, it greatly impedes it.

The State Committee on Science and Technology is the principal agency coordinating overall R&D in the USSR, but its responsibilities in this area are shared with the State Planning Commission (Gosplan) and the USSR Academy of Sciences. The State Committee on Science and Technology works out the details of plans for R&D, "especially those regarding the introduction of new technology"[39] with Gosplan. The USSR Academy of Sciences must be consulted whenever the planning of research involves the natural and human sciences.

In actual practice, the realization of the research plans involves the cooperation of other government bodies. The State Committee on Material and Technical Supplies controls sales of materials and equipment to research establishments. The State Committee on Construction controls the building of scientific establishments as well as that of the production enterprises. The Ministry of Higher and Secondary Education influences the availability of personnel. The State Committee on Wages and Labor controls the way research personnel may be used. Gosbank ensures that the research institutions conform with the targets and norms of the National Economic Plan. This kind of cumbersome machinery for

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[39] Eugene Zaleski, "Central Planning of Research and Development in the Soviet Union," in Eugene Zaleski et al., *Science Policy in the USSR* (Paris, France: Organization for Economic Cooperation and Development, 1969), p. 404.

the planning of research has not hindered the development of computers in Western countries.

Both forces and funds are widely diffused among the many design bureaus and scientific research institutes, which in turn are under the authority of various ministries. "Each has its own viewpoint and its own technical policies for its factories, scientific research institutes, and computer engineering design bureaus. Quite often, inexplicable parallelism and overlap are noted, and the same elements, circuits, components, and even machines are created in different jurisdictions."[40] Probably worse than the wasteful duplication of effort is the lack of coordination, which results in an incomplete and unreliable end product.

Research and development of computer hardware historically began in the institutes in the USSR Academy of Sciences system, and some of the best research is still conducted there. However, the Ministry of the Radio Industry and the Ministry of Instrument Construction, Means of Automation, and Control Systems (Minpribor) now also perform a major share of the R&D work. Other organizations contribute a smaller amount of R&D on computer hardware--the Ministry of the Electronics Industry and the State Committee on Science and Technology, for example. Computers are being designed by the design bureaus in many of the research institutes, but at least two important design bureaus are attached to Soviet production facilities under one of the ministries: the Design Bureau of the Minsk Ordzhonikidze Computer Factory and the Design Bureau of the Penza Electronic Computers (VEM) Plant,[41] both under the Ministry of the Radio Industry.

Production of computer hardware is controlled mainly by Minpribor or by the Ministry of the Radio Industry, but production of other components of the computer system involves a number of other organizations

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[40]Golovachev, op. cit., p. 721.

[41]There seems to be some confusion among reports in the Soviet press as to the proper name for this plant. The Penza Electronic Computers (VEM) Plant may very well be the successor to or a remodeled version of the Penza Calculating and Analytical (SAM) Plant. The Penza SAM Plant was scheduled to be rebuilt on its previous site in the late 1960s. There is also the possibility that they are two separate plants.

(see below). Responsibility for customer services has been forced upon the Ministry of the Radio Industry and upon Minpribor, but so far it is poorly organized.

The linkages between the work of the research institutes, design bureaus, and the production facilities have in many cases been weak. (The computer design bureaus do not seem to function as independent organizations, but are usually attached either to a research institute or to a manufacturing plant.) The chief problem appears to be that computer design is often undertaken without regard to the particular facilities of the plant, i.e., without taking into account the amount of retooling needed to achieve a given configuration. The design bureaus attached to particular plants, such as the Minsk Ordzhonikidze Computer Factory and the Penza Plant, seem to have done most of their own development work as well, so there have been fewer problems of this nature. But where development and design are primarily done away from the production facilities, there seems to be a trend toward sending representatives of the research institutes to the plant to help organize the production processes.

The particular nature of the product resulting from the R&D effort is also not taken into account. Unlike television sets, computers do not constitute a single unit but are entire systems with a number of vital components. "A computer" consists both of hardware--i.e., the main frame and peripheral equipment, such as input-output devices--and software, including an operating system and programs to carry out specific functions. Moreover, in order for a customer to use a computer, installation, maintenance, and trained computer personnel are necessary. Thus, to produce computers successfully, careful attention must be given to all components of the system, not merely to the main frame.

The gap between the development of the hardware and the software has been particularly troublesome. The Institute of Mathematics of the Belorussian SSR Academy of Sciences, which was responsible for developing the software of the Minsk-32, did not receive a unit of the machine until a year and a half after the computer went into production.[42]

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[42] M. Korolev, "Sem' nyanëk vokrug EVM" ["Seven Nannies Around a Computer"], *Pravda*, October 9, 1972, p. 2.

Fragmentation occurs again in the production of a computer system. The hardware is handled mainly by the agencies mentioned above. Peripherals are designed and produced by some of the same organizations that produce the hardware, but they are also produced by other research institutes in the Academy of Sciences system and other production facilities in the Ministry of the Radio Industry and in Minpribor. Software is developed by some of the institutes that develop hardware, but more often by a completely different set of Academy of Sciences institutes. The users themselves develop a great deal of software, often in conjunction with an Academy of Sciences institute or another research institute. Computer personnel are trained in some cases by research institutes; in others, by computer plants; and in still others, by the Ministry of Higher and Secondary Education.

The quality of these system components varies according to the producer. The important point to be made here is that "the quality of each of these units to an equal degree determines the quality of operation of the entire machine. For example, a malfunction in the information output mechanisms brings to nought the proper operation of the central processor."[43] "Computer technology" is not really a single technology but cuts across many different technologies, which include such diverse fields as electronics, chemicals, papermaking, magnetics, and so on. In the Soviet Union, these technologies are handled by a variety of organizations. Much of the electronic components development and production is done in the Ministry of the Electronics Industry, and electric motors and wires are supplied by the Ministry of the Electrical Engineering Industry. Punchcards and papertapes come from the Ministry of the Pulp and Paper Industry, magnetic memory tapes from the Ministry of the Chemical Industry, and so on. All of these additional organizations influence the production of computers by their ability or inability (or perhaps more accurately, by their willingness or unwillingness) to supply reliable elements needed to produce a computer system.

It has often been noted that the organization of American computer

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[43]Aven, op. cit., p. 15.

production appears to be equally untidy,[44] with many companies involved at various levels; but in practice, a high degree of coordination exists. Without it, an American computer company simply wouldn't survive. Under the Soviet system, the fragmentation of the industry across many ministerial lines--a problem American computer producers don't have to worry about--results in much duplicated effort and wasted resources. Each ministry tries to protect its own production from the production uncertainties of other ministries in terms of essential computer elements.

CONFLICT AND CONTROVERSY IN THE SOVIET COMPUTER INDUSTRY

Besides the vertical and horizontal fragmentation of the Soviet computer industry, and the peculiarities of the planning and managerial system in which it performs, resistance to the introduction of computers and conflict over the future trends of the industry have impeded its progress.

Many practical ideological considerations are involved in the resistance to the introduction of computers. Some of the practical considerations are discussed below, while more information about ideological resistance to computers will be found in Section III, under "Early Computer Development, 1948-1954."

Computers are a mixed blessing in any country. They cause dislocations, displacing not merely jobs but the people who perform those jobs. They reveal inefficiencies in the traditional modes of operation, and perhaps even corruption. They shift organizational patterns of control. They affect not only the *way* things get done, but they may also change *what* things get done. In other words, they can cause radical changes in the organizations in which they are used.

It is a human trait to dislike change, especially when it is impossible to predict its net effect. The Soviets, in general, tend to be more conservative about change than Americans, and less oriented toward new technology. Change in the cumbersome Soviet economic system is clearly needed, and many far-sighted Soviet political leaders

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[44] Judy, op. cit., p. 68.

believe that radical change, based on up-to-date technology, is desirable. A number of these same people also realize that the use of computers should have long-term economic benefits and, indeed, without computers to process the already enormous and ever-increasing amount of data required in a central planning system, that system may eventually break down.

The seriousness of these rapidly increasing demands is revealed in the following statement:

> It has been calculated that by 1975-1980, it will be necessary to engage almost the entire adult population in the sphere of national economic planning and management if methods of managing the national economy are not changed and immediate measures for the automation of these processes are not adopted. . . .[45]

Stated more conservatively: "The quantity of economic information necessary for the development of national economic plans has increased approximately thirty-fold in the past 20 years."[46] The implications of this increase in required information are obvious. Although the extrapolations are probably exaggerated, they serve to demonstrate the Soviets' fear that their economic data requirements will outstrip their capabilities for handling them.

Soviet bureaucrats, on the other hand, are likely to see the introduction of computers from their own narrow point of view. Some may simply be unable to understand the principles of computers, particularly if their experience predates the electronics era. Many of these

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[45] G. A. Spynu and V. T. Muzychuk, "Mekhanizatsiya i avtomatizatsiya inzhenernogo i upravlencheskogo truda" ["The Mechanization and Automation of Engineering and Administrative Labor"], *Mekhanizatsiya i avtomatizatsiya upravleniya*, No. 3, May-June 1967, pp. 1-4; excerpts translated in *Soviet Cybernetics: Recent News Items*, No. 9, October 1967, p. 47.

[46] V. M. Tsmel', "Avtomatizatsiya raschetov narodno-khozyajstvennogo plana" ["Automation of Calculations for the National Economic Plan"], in the journal *Mekhanizatsiya i avtomatizatsiya upravleniya* [*Mechanization and Automation of Management*], No. 2, 1967, pp. 1-4; translated in *Soviet Cybernetics: Recent News Items*, No. 10, November 1967, p. 61.

bureaucrats occupy their positions not because of their intellectual and managerial abilities, but because of their party status. Thus, they may be afraid that they won't be able to control this complex machinery that they can't even understand. Others may be more knowledgeable about computers and welcome them as a means of lightening their workloads. Still others may see the introduction of computers as a threat to the bureaucratic empires they have built. This fear is evidenced in the reluctance of many organizations to share the use of computers located close to them but under another organization's control. Many will simply lose their enthusiasm for computers when no one arrives to uncrate and install the machine, or to debug an unreliable machine, or to maintain and repair a reliable machine, or to write the programs necessary to use it. Furthermore, as of 1967, installing a computer and putting it into operation often took as long as a year, and normal operations were said to begin "only after 2 to 3 years."[47]

This resistance to the introduction of computers is reflected in an on-going debate about the best approach to computerizing the Soviet economy. Soviet planners envision that eventually all computers used for management of the economy, at all levels, from the top planning agencies down to the individual industrial enterprises, will be linked into one gigantic computer network. The question is whether the linking should begin "from the bottom up or the top down," and how extensive the functions of such a system should be.[48] Plans for creating a statewide automated management system, based on a state network of computer centers and on a unified automated communications network, are going forward, in spite of the fact that the Soviet computer

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[47] Sh. Kamaletdinov, "Esli tsentry--to krupnye" ["If There Are Centers, Let Them Be Big Ones"], *Pravda*, August 5, 1967, p. 2; translated in *Soviet Cybernetics: Recent News Items*, No. 8, September 1967, pp. 31-32.

[48] I. Ya. Birman, "Edinaya set' vychislitel'nykh tsentrov" ["Unified Network of Computer Centers"], Chapter 5 of *Metodologiya optimal'nogo planirovaniya* [*Methodology of Optimal Planning*], Mysl' Publishing House, Moscow, 1971, pp. 125-128; translated in *Soviet Cybernetics Review*, Vol. 2, No. 5, September 1972, pp. 13-15.

industry cannot yet produce sufficient numbers of computers to meet the demands of such a system.[49]

Resistance to the introduction of computers in the Soviet Union is complicated by a disagreement about the best path to follow in their development. Should the Soviet computer industry concentrate its resources on developing more digital machines or on analog machines? Analog machines are less expensive to develop and produce than digital machines but their uses are more limited. Should the digital machines that are developed be general purpose or special purpose? General-purpose machines can be adapted to a wide variety of uses, but again they may cost more to develop and produce than special-purpose machines, particularly when the user may have to bear the responsibility (and probably the cost) of developing the software and perhaps even the peripherals for his particular needs. Based on very limited evidence, it appears that the Soviets are producing a fairly large number of analog and special-purpose machines to meet industrial needs that are being met in the United States by general-purpose machines.

Conflict about the introduction of computers is likely to continue in the Soviet Union for some time, and until it is more or less resolved, it will tend to weaken the already diluted demand for computers. The various methods by which the Soviet government has attempted to cope with these far-reaching and chronic problems will be discussed in Section III.

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[49] D. Zhimerin, "Problemy avtomatizirovannoj sistemy upravleniya ekonomikoj" ["Problems of an Automated System for Managing the Economy"], March 16, 1972, translation of the complete paper in *Soviet Cybernetics Review*, Vol. 2, No. 6, November 1972, pp. 17-28.

III. PARTY-GOVERNMENT INTERVENTION IN THE SOVIET COMPUTER INDUSTRY

Until the early 1960s, the Soviet computer industry could hardly be termed an industry, even in the narrow sense of comprising "a distinct group of productive enterprises."[1] Research on computers and computer-related topics was being conducted, and designs were being formulated, but very little attention was being paid to any large-scale production of computers. In this context, the Soviet computer industry is much younger than the American computer industry, which was off to a vigorous start by the 1950s.

The nine leading U.S. computer-manufacturing companies, as of 1969, had all begun to produce computers by 1961. IBM switched from punched-card office machines to computers in 1953. UNIVAC installed its first commercial computer in 1951. The Burroughs Corporation followed these two leading companies in 1954; Honeywell Corporation, in 1955; General Electric, in 1956; Control Data Corporation, in 1958; RCA, in 1959; NCR, in 1960; and Scientific Data Systems, in 1961.[2] In contrast, by 1961, there were only three Soviet computer production facilities: The Moscow Calculating and Analytical Machines (SAM) Plant, which began manufacturing computers in 1953; the Penza Calculating and Analytical Machines (SAM) Plant, beginning in 1955; and the Minsk Ordzhonikidze Computer Factory, in 1960. Not only were there far fewer production facilities, but also capacity in the Soviet plants was a fraction of that in the American plants.

Of the nine leading U.S. computer companies mentioned above, four had evolved from business machines companies and three from electronic equipment companies; only two were new companies manufacturing only electronic data processing equipment. Obviously, the fact that the business machines and electronic equipment industries were already well developed in the United States contributed to the early and strong growth

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[1] *Webster's Seventh New Collegiate Dictionary*, p. 430.

[2] Eric A. Weiss (ed.), *Computer Usage Fundamentals* (New York: McGraw-Hill Book Company, Inc., 1969), pp. 54-61.

of U.S. computer manufacturing. In the Soviet Union, neither industry was well developed when computers became an important new item.

PRIORITY OF THE SOVIET COMPUTER INDUSTRY

Besides the need for an industrial and technical base on which to build their computer industry, the Soviets must also establish the necessary priority of the industry. It is important to distinguish among the various meanings of the term "priority." In this report, the term will be used to mean "something meriting prior attention."[3] In this context, then, "priority" will mean that the Soviet leadership considers the problem to be of great importance. This is the notion of priority in itself, apart from any attempts to implement that notion. Another definition of priority calls it a "preferential rating, especially one that allocates rights to goods and services usually in limited supply."[4] The two definitions are often equated, but it may be important to make the distinction. Analysts of the Soviet economy often try to determine how important a given industry is to the Soviet leadership by observing the amount of goods and services (and sometimes the quality) delivered to it. This may be one indication of assigned priority, but it should not be construed as the only one. Political attention may be another indication of priority and should not be overlooked, even when economic evidence has not yet been revealed. In the Soviet Union, there is a long lag between political decisions and economic implementation, and since the major economic plans are drawn up at least 5 years in advance, the effects of political changes in priorities may not be fully visible for a long period of time.

Another trap that the analysts sometimes fall into is one of assuming that priority equals success. Logically, this statement does not necessarily hold true, and empirically it does not always hold true even in a centralized economy such as the Soviet Union. Soviet space and military successes have often been cited as examples of the proposition that priority equals success. The failures in the Soviet space

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[3] *Webster's Seventh New Collegiate Dictionary*, p. 677.

[4] Ibid.

and military programs are, however, conveniently overlooked. Therefore, the priority of a given program cannot be inferred to be low only on the basis of failures in that program. The notion that indifference to the importance of the task at hand is the only possible cause of failure is a very simplistic one.

In the United States, implementation of a high-priority civilian program is determined not only by government interest in it but also by market forces--customer demand, returns to risk, and so on. These factors also tend to interact rather directly and quickly. It is tempting to say that in the Soviet Union, implementation rests solely on certain top-level decisions, since the Soviet economy is much more centralized. However, the jurisdiction of the resources allocated may be as important in the implementation of a priority program as the absolute amount of those resources.[5] Changing existing jurisdictional arrangements has an extremely high cost in the Soviet Union, and this cost must be taken into account in evaluating the priority of any particular industry or program.

Priority is never absolute, even in a centralized economy, but involves economic tradeoffs. Having a strong defense sector is not enough in itself to keep a nation going; its economy must also be reasonably viable. The economic tradeoffs will probably not be made at only the gross level of how much an individual industry contributes to the strengthening of the national economy and/or defense. Thus the importance of the computer industry will vary according to the Soviet leadership's perception of its contribution to the Soviet economy and defense. Presumably the cost of this contribution will also be taken into account insofar as possible.

MECHANISMS OF INTERVENTION

With this background in mind, let us look at the historical evolution of Soviet R&D and production of computers and at the mechanisms by which the Soviet Communist Party and the government have tried to inspire greater effectiveness of the computer industry. These mechanisms

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[5] See the discussion on "Planning and Management of R&D Production" and on "Fragmentation of the Soviet Computer Industry" in Section II.

include: (1) a relocation of some of the R&D formerly done in the Academy of Sciences institutes to ministry institutes; (2) the use of economic and prestige incentives (e.g., by denying or awarding State Prizes or the Mark of Quality); (3) control of production through the ministries; (4) intervention through budget control (particularly at the State Plan level), usually with the influence of Gosplan; (5) directives to existing government organs, especially the main computer-producing ministries; (6) formation of the State Committee on Science and Technology of the Council of Ministers of the USSR to be a new agency with broader coordinating responsibilities for the computer industry as well as many other agencies; (7) creation of a computer *obedenie* or production association; (8) direct intervention by agreements with foreign governments to produce an intergovernmental (Soviet and East European) series of computers, the Ryad line; (9) importation of foreign computers; and (10) increased centralization of domestic R&D effort in the recently announced tie-in of the ASVT work with the Ryad line of computers.

EARLY COMPUTER DEVELOPMENT, 1948-1954

The first Soviet computer, the MESM, was designed in 1948-1951. But it was not until 1953, the year of Stalin's death, that the Soviets put a computer (the Strela) into production. During this period, most of the computer R&D was centered in the Academy of Sciences system. The MESM (Russian acronym for "small computer") was designed in 1948, tested in 1950, and modified in 1951 by an institute of the Academy of Sciences of the Ukrainian SSR in Kiev. This institute, headed by Academician S. A. Lebedev, became the Computer Center of the Academy of Sciences of the Ukrainian SSR in 1956, headed by V. M. Glushkov. After Lebedev's transfer to Moscow around 1950 as head of the newly formed Institute of Precise Mechanics and Computer Engineering, under the USSR Academy of Sciences, he also designed the first large-scale Soviet computer, the BESM (Russian acronym for "large machine"), completed in 1952. Other early digital computers, the M-1 (1951) and the M-2 (1953), were designed by I. S. Bruk at the Moscow Institute of Electronic Control Computers of the USSR Academy of Sciences. The Strela is the only early (pre-1954) machine known to have been designed by a government agency, the

Institute of Mechanics and Instrument Design of the Ministry of the Radio Industry, a ministry that continues to be prominent in the development of Soviet computers.

The focus of this early period on machines for scientific applications persisted in the Soviet Union long after the United States had begun to make extensive use of computers in economic applications. In the words of one Soviet academician,

> Our first machines were created exclusively for specific and technical calculations to the extent required in the new technologies. As far as the application of computers in economic computations was concerned, their potential in this respect was not fully appreciated and was even questioned by many economists.[6]

During this early period of development, there were not many overt signs of party or government intervention aimed at accelerating the progress of the incipient Soviet computer industry. In fact, the opposite seems to have been true. Upon publication in the United States of Norbert Wiener's well-known book on cybernetics,[7] a number of articles appeared in Soviet publications denigrating cybernetics,[8] and by implication, the use of computers for anything but the solution of the most straightforward computations in the physical sciences. The anticybernetics movement peaked in 1953 with the publication of a pseudonymous article in the "Criticism of Bourgeois Ideology" section of the journal *Voprosy Filosofii* [*Problems of Philosophy*]. The article, entitled "Whom Does Cybernetics Serve?" attacked cybernetics as "one of those *pseudosciences*

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[6] A. Dorodnitsyn, "Narodnoe khozyajstvo i vychislitel'naya tekhnika" ["The National Economy and Computer Technology"]; translated in *Soviet Cybernetics: Recent News Items*, No. 6, July 1967, p. 51.

[7] *Cybernetics, or Control and Communications in the Animal and the Machine* (London: Chapman & Hall, Ltd., 1949).

[8] It should be noted here that the term "cybernetics" is used differently in the Soviet Union than it is in the United States. According to Norbert Wiener, the U.S. definition of cybernetics refers to "the entire theoretical aspect of control and communication both in the machine and in the human organism," particularly feedback mechinisms. The Soviet definition is broader and includes most applications of computer technology as well.

which are generated by contemporary imperialism and are doomed to failure even before the downfall of imperialism."[9]

In the same vein, the 1954 edition of *The Concise Philosophical Dictionary* defined cybernetics as a "reactionary pseudoscience."[10] But by 1954, the tide had already turned, and cybernetics was being defended in lectures and, in the following year, in writing. The 1955 edition of *The Concise Philosophical Dictionary* did not include an entry on cybernetics at all, suggesting that the topic was still very much open to question.[11]

It is difficult to assess just how much effect the anticyberneticians had on the future course of Soviet computer development. At least one Western writer on Soviet cybernetics seems to believe that the effect on the actual production of computers was negligible, since some computers were created during this early period.[12] But the creation of a few hand-tooled machines, all for use in the physical sciences, does not a computer industry make. The conservatism of some Soviet scientists toward the new technology, an inhibiting force in its own right, was no doubt intensifed by the anticybernetics movement. The anticyberneticians also inhibited another potential source of influence on computer development, the future customers. Traditionally, the Soviet customer has had a much more limited impact on production than has the American customer. Nevertheless, what little impact the potential Soviet customer might have had during this early period--an impact that was vital to the rapid development of the American computer industry--was no doubt tempered by a reluctance to request an ideologically controversial product.

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[9] "Materialist," "Komu sluzhit kibernetika" [Whom Does Cybernetics Serve?"], *Voprosy Filosofii* [*Problems of Philosophy*], No. 5, 1953, pp. 210-219; translated in *Soviet Cybernetics: Recent News Items*, Vol. 7, August 1967, p. 47.

[10] I. V. Branev, "Biography of Academician A. I. Berg," *Soviet Cybernetics: Recent News Items*, Vol. 3, No. 3, March 1969, p. 21.

[11] David Holloway, "Innovation in Science: The Case of Cybernetics in the Soviet Union," *Science Studies*, No. 4, 1974, p. 319.

[12] Ibid.

The anticyberneticians' early resistance to the introduction of computers in the Soviet Union centered around their use in fields that would undoubtedly have special social and political impacts, i.e., in the natural sciences, particularly in biology and physiology, and in the economy. The use of computers for solving problems in the physical sciences was certainly politically acceptable. It seems likely, however, that the weakening of customer demand for computers to be used for a variety of nonscientific purposes contributed to the lag in computer development in the Soviet Union. In the author's opinion, the 1960 comment of Academician A. I. Berg, now the First Chairman of the Scientific Council on Cybernetics of the Presidium of the USSR Academy of Sciences, that "it took such a long time to form a sensible attitude to cybernetics that undoubted harm was done to our science and technology" is not an exaggeration of the state of computer technology at that time.[13]

Although Norbert Wiener's book[14] was published in the Soviet Union some 10 years after it originally appeared in the United States, and although a Science Council for Cybernetics under the USSR Academy of Sciences was established in 1959, a climate of suspiciousness toward cybernetics had been created which would prove difficult to overcome. Acknowledgment of some anticybernetics holdouts was noted as late as 1971, in an article describing important trends in cybernetics, following the 1970 Conference on the Philosophical Problems of Cybernetics held in Moscow by the USSR Academy of Sciences.[15] This early period clearly left its mark on the course of the future development of the Soviet computer industry.

INDIRECT INTERVENTION, 1955-1965

In the mid-fifties, Soviet interest in cybernetics grew, and the subject became, if not totally politically respectable, at least

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[13] Ibid., p. 312.

[14] Wiener, op. cit.

[15] I. Gutchin, "Optimization of Reason," *Moscow News*, No. 46, November 1970, p. 11.

tolerable for purposes of discussion. The practical use of computers was being demonstrated domestically in military and space applications. The success of the application of computers to a variety of tasks in other countries, irrespective of their ideological orientations, was being more and more appreciated. By the late 1950s, both Soviet and foreign works on cybernetics were being published (the latter with appropriate editorial caveats about any ideological content). As the anticybernetics movement died down in the late fifties, Soviet computer technology began to be developed on a more serious scale.

In April 1959, the Presidium of the USSR Academy of Sciences created a Science Council for Cybernetics. One of the eight original sections of the Science Council for Cybernetics dealt with mathematical machines. The special role of the Science Council for Cybernetics has been described in the following way:

> Although it does not itself conduct research, the Council has played a crucial role in the development of Soviet cybernetics; it has drawn up lists of the most important research topics for inclusion in the Academy's coordinating plans, and has monitored the conduct of this research; it has organized conferences, symposia and seminars; and it has sponsored publications.[16]

Actual research and development on computer hardware was carried on in the research institutes, which proliferated between 1955 and 1965 and which developed important new computers. Some of these institutes evolved within the Academy of Sciences system; others were transferred to or formed under the aegis of the Ministry of the Radio Industry or the Ministry of Instrument Construction, Means of Automation, and Control Systems (Minpribor), which were becoming the major computer-producing ministries. Still others sprang up in less-auspicious locations, under the joint control of the State Committee on Science and Technology and the USSR Academy of Sciences, for

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[16] Holloway, op. cit., p. 325.

instance, and in the Ministry of the Electronics Industry. The pattern of this expansion of R&D organizations will be laid out below.[17]

Within the Academy of Sciences system, two new important computer R&D institutes grew out of computer centers established earlier. The Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR evolved in 1962 from its predecessor, the Computer Center of the Academy of Sciences of the Ukrainian SSR. As the institute's name implies, the work it undertakes is not confined to computer hardware, but also includes research on all aspects of cybernetics. The Kiev, Dnepr, and Promin' computer lines were its most important early hardware products. The Scientific Research Institute of Mathematical Machines of the Academy of Sciences of the Armenian SSR, established in 1956, also came out of a small group, this one located at the Computer Laboratory of the Institute of Mathematics and Mechanics of the Academy of Sciences of the Armenian SSR. Development of both of its widely used early computer lines, the Razdans and the Nairis, began in the early 1960s.

Three R&D organizations under the Ministry of the Radio Industry became prominent during this period. The Design Bureau of the Minsk Ordzhonikidze Computer Factory began work on the important Minsk line of scientific computers around 1956. Also in the mid-1950s, the Design Bureau of the Penza SAM Plant took over the design of the Ural line of data-processing machines from work done earlier at the Institute of Mechanics and Instrument Design under the same ministry. A less-important institute from the standpoint of computer hardware development, but important in computer software, is the Scientific Research Institute of Calculating Machine Construction (NIISchetmash). Most of its work on hardware, for instance on the Era computer and the ATE-80 punchcard calculator, was done in the early 1960s.

The only computer hardware R&D institute to emerge between 1955 and 1965 under Minpribor was the Severodonetsk Scientific Research Institute of Control Computers. This institute, which developed the

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[17] The following discussion only identifies the institutes that began important work in this period. For more details about individual institutes, see Section IV, "Soviet Computer Research and Design Organizations."

MPPI-1, UM-1, and KVM-1 control computers, was well known by the early 1960s.

An organization that did a limited amount of work on computer hardware in this period was the Laboratory of Electromodeling (LEM) of the All-Union Institute of Scientific and Technical Information (VINITI). This laboratory operated under the joint control of the USSR Academy of Sciences and the State Committee on Science and Technology. It produced the LEM machines, which were small general-purpose digital computers.

One computer R&D institute was established outside of the Academy of Sciences system and the two computer-producing ministries, only to find its jurisdictional location a great handicap. The All-Union Scientific Research Institute of Electromechanics (VNIIEM) of the Ministry of the Electronics Industry began a line of computers bearing its initials in the early 1960s, but could not find a ministry willing to produce them.[18]

By 1956, there were as many as 16 separate series of Soviet computers (although most of these were produced in very small numbers). Apparently little or no coordination existed among research, design, and production, and between the development of hardware and software. This resulted in a good deal of overlap and duplicated effort, much of it due to the ministerial rigidities (discussed in Section II) that prevailed before 1957 and after 1965. According to one Soviet engineer: "Having different ministries is like having different governments."[19]

By 1961, the possibilities for the use of computers in the Soviet economy had been given official recognition in the Program of the Communist Party of the Soviet Union adopted by the 22nd Congress of the CPSU on October 31, 1961. The Program stated:

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[18] See the discussion on "Planning and Management of R&D and Production" in Section II for further details.

[19] V. Golovachev, "Rozhdaetsya Gerkules chto sderzhivaet razvitie elektronnoj vychislitel'noj tekhniki v strane" ["A Hercules Is Born That Is Retarding the Development of Electronic Computer Technology in the Country"], *Trud* [*Labor*], March 19, 1967, p. 3; translated in *Soviet Cybernetics: Recent News Items*, No. 5, June 1967, p. 72.

> Cybernetics, electronic computer and control systems will be widely applied in production processes in industry, building and transport, in scientific research, planning, designing, accounting, statistics and management.[20]

Nevertheless, the Soviet computer industry still suffered from the low priority assigned to it at that time, with a concomitant lack of central direction. Nominally, the Main Administration for the Introduction of Computer Technology under the State Committee on the Coordination of Scientific Research Work of the USSR had primary responsibility for the development and application of computer technology between 1961 and 1965, but it was obviously ineffective.[21]

Beginning in October 1965, the functions of the State Committee on the Coordination of Scientific Research were taken over by the State Committee of Science and Technology. Whereas the State Committee for the Coordination of Scientific Research was responsible for "the co-ordination of R&D, improvements in planning and in the introduction of new techniques, and the discontinuation of projects no longer necessary, the new Committee has the task of 'ensuring the cohesion of state policy in the field of scientific and technical progress'."[22] Determining basic trends in the development of science and technology--including, of course, computer technology--was part of this responsibility.

Another major reason for the confused situation of that time is that both the bureaucratic structure of industry and the administration of applied research and development were reorganized several times. The industrial ministries were abolished in 1957 and replaced by a

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[20] *Program of the Communist Party of the Soviet Union* (New York: Crosscurrents Press, 1961), p. 75; translation by the Novisti Press Agency (APN).

[21] V. M. Glushkov, A. Dorodnitsyn, and N. Fedorenko, "O nekotorykh problemakh kibernetiki" ["Some Problems of Cybernetics"], *Izvestiia*, September 6, 1964, p. 4; translated in *Soviet Cybernetics: Recent News Items*, No. 6, July 1967, p. 45.

[22] Eugene Zaleski, "Central Planning of Research and Development in the Soviet Union," in Eugene Zaleski et al., *Science Policy in the USSR* (Paris, France: Organization for Economic Cooperation and Development, 1969), pp. 57-58.

combination of *sovnarhozy*, or regional economic councils, and state committees overseeing particular industries, especially defense-related industries. In September 1965, the *sovnarhozy* were abolished and the state committees became ministries. "During this period there was much reshuffling in the jurisdiction of research institutes."[23] Thus, between 1957 and 1965, the major computer research institutes came under state committees or Gosplan and the smaller ones came under the *sovnarhozy*. This system complicated the problem of communication, with the major research institutes under the central control of the state committees cut off from production facilities in the *sovnarhozy*, and the smaller research institutes in the *sovnarhozy* isolated from one another by local rigidities instead of ministerial rigidities.[24]

The functions of the present-day Ministry of the Radio Industry were obviously considered important to defense; unlike many other ministries, its activities were not disrupted by transfer to the *sovnarhozy* in 1957 but were taken over by the State Committee for Radioelectronics between 1958 and 1965.[25] The predecessor of the State Committee for Radioelectronics was the Ministry of the Radiotechnical Industry (1954-1958). In a notably different pattern, the functions of the present-day Minpribor seem to have been more subject to reorganization. The origins of Minpribor go back to 1954, when the Ministry of Machine and Instrument Building became an organization separate from the Ministry of Machine Building. In 1956, the Ministry of Machine and Instrument Building split into two separate ministries, the Ministry of Instrument Building and the Means of Automation and the Ministry of Machine Building. In the middle of 1957, the activities of these two ministries were turned over to the *sovnarhozy*, and remained there until early 1959, when the State Committee for Automation and Machine Building was

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[23]Ronald Amann, M. J. Berry, and R. W. Davies, "Science and Industry in the USSR," in Eugene Zaleski et al., op. cit., p. 404.

[24]A more detailed analysis of these problems appears in ibid., pp. 432-434.

[25]The following information was derived from the chart, "Evolution of the Central Administrative Structure of the USSR," Central Intelligence Agency, Washington, D.C., August 1972.

created. In 1963, a number of more specialized state committees were formed out of the original State Committee for Automation and Machine Building. One of these was the State Committee for Precision Instruments, Automation Equipment and Control Systems. In 1965, this State Committee became the Ministry of Precision Instruments, Automation Equipment and Control Systems.

A major reform of the Academy of Sciences system also took place in the late 1950s and early 1960s, which constituted indirect intervention in the computer industry on the part of the Party and the government. Reform of the Academy of Sciences system has taken place several times since the Soviets came into power, but these reforms have focused on the poor coordination of research and on the overlap between the Academy institutes in the technical sciences and the research institutes of the industrial sector. The reform of 1961 was a response to criticism by N. S. Khrushchev at the plenary session of the Central Committee of the CPSU in June 1959, and to a new statute for the Academy, approved by the Central Committee, also in June, directing the Academy to prepare plans for the study of key problems. According to the 1959 statute, the USSR Council of Ministers would continue to make suggestions for theoretical research to be conducted by the Academy, but the Academy could now distribute research among its divisions and institutes on its own and create new research organizations. "The Academy was [also] directed to establish close contacts between research organizations and industrial enterprises."[26]

In April 1961, the Central Committee of the CPSU and the USSR Council of Ministers issued a decree called "Measures for Improving the Coordination of Scientific Research in the Country and the Activities of the USSR Academy of Sciences." The resulting reform of 1961 was designed to minimize the role of the Academy of Sciences in applied research so as to focus on theoretical problems considered to be highly important, including cybernetics. At this time, "the industrially oriented and branch specialised institutions of the Academy were transferred to the appropriate state committees (ministries since September

[26] Helgard Wienert, "The Organisation and Planning of Research in the Academy System," in Eugene Zaleski et al., op. cit., p. 201.

1965). The size of the Academy's Division of Technical Sciences was greatly reduced."[27] The Institute of Precise Mechanics and Computer Engineering (Lebedev's institute) was one of the institutes transferred from the Division of Technical Sciences, apparently to the State Committee for Radioelectronics, but "the USSR Academy retained scientific and methodological control."[28] At the same time, the Division of Technical Sciences was reorganized into four main sections, including research institutions on automation and cybernetics.[29]

Also in April 1961, some new science councils were created to coordinate interdisciplinary research on problems considered to be of prime importance. Science Councils for Major Complex and Inter-Branch Scientific Technical Problems were attached to the State Committee for the Coordination of Scientific Research (the predecessor of the All-Union State Committee for Science and Technology), and Science Councils for Major Complex Problems in the Natural and Social Sciences were attached to the USSR Academy of Sciences.[30] "The 27 Science Councils for Complex Problems of the USSR Academy were directly attached to the Presidium, in order to emphasize their high status within the Academy hierarchy."[31] When, in 1963 and 1964, the science councils were reorganized and "removed from the direct control of the Presidium [of the USSR Academy of Sciences] and attached to the newly-created Sections and Divisions, in order to bring them into closer contact with the research establishments,"[32] the Council for Cybernetics was one of only two science councils remaining under the direct control of the Presidium, an indication of the rising importance of this field.

These councils function chiefly as advisory and coordinating bodies, and it is not clear whether they have the authority to carry

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[27] Ibid., p. 202.

[28] Ibid., p. 225.

[29] Ibid., p. 226.

[30] Ibid., pp. 228-229.

[31] Ibid., p. 229.

[32] Ibid., p. 230.

out their assigned functions. Clearly they do not have budgetary powers. However, according to Helgard Wienert,

> The science councils, especially the Complex Councils serve as important indicators of fluctuations in government policy and of the new directions which it is taking. The areas for which they are created, the reorganizations to which they are subjected, their working facilities, as well as the research projects which they favour, very often faithfully reflect the various aims of Soviet science policy. At the same time, the science councils serve the important purpose of drawing scientists into the higher circles of decision-making, thus enabling them to help formulate and implement policy on a national scale.[33]

As of 1965, science councils attached to the State Committee for Science and Technology included those of Automization and Mechanization of Productive Processes (1962); Electronic Technology (1965); and Development and Introduction of Mathematical Methods of Computated Techniques and of Automatic Systems of Control and of Processing of Information into the National Economy (1965) (headed by Academician V. M. Glushkov, President).[34]

In November 1962, the Academy of Sciences was again criticized by Khrushchev for having developed "powerful applied research institutes," but at the same time, closer ties between research and development were advocated.[35] In April 1963, a decree of "Measures To Improve the Activity of the USSR Academy of Sciences and the Academies of Sciences of the Union Republics" was issued. The purpose of this decree was to strengthen the leadership of the USSR Academy of Science in fundamental science and to coordinate research with non-Academy institutes. At the same time, most of the remaining industrially oriented research was transferred from the Academy of Sciences to appropriate state committees. Some key military and space research institutes were transferred at that time, giving the government more control over those areas.

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[33] Ibid., p. 231.

[34] Ibid., p. 127.

[35] Ibid., p. 226.

Unfortunately, information about computer research institutes transferred in 1963 or later is almost totally lacking. An article published in 1967 does indicate, however, that most of the computer research institutes were transferred to the Ministry of the Radio Industry, or perhaps to its predecessor, the State Committee on Radio-electronics.[36] This move gave the Soviet government more control over computer research, which had space and military applications. At the same time, the transfers left a number of enterprises under Minpribor "without scientific guidance."[37] For this reason, Minpribor "enterprises have begun to create their own design bureaus and scientific research institutes. There is a diffusion of forces and funds, and 'parallel' design bureaus and institutes multiply. . . ."[38]

In spite of these somewhat incidental Party-government moves toward greater control over computer R&D, certain computer institutes have enjoyed considerable autonomy compared with institutes in other fields. These are mainly head institutes,[39] or eminent institutes in their field that have been given the responsibility of helping to coordinate R&D and to eliminate duplication. The coordinating powers of some head institutes in the computer industry have been "reinforced by their having financial control over parts of the work delegated to subordinate institutes. The Institute for Precision Mechanics and Computing Techniques (of the USSR Academy), for example, had financial control over subordinate institutes during the development and design stages of the M20 Digital Computer [around 1957]."[40] This is not typical of institutes in other fields and no doubt has contributed to the growth of the nongovernment power bases observed in Soviet computer policymaking.

Party-government concern with the computer industry was growing

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[36] V. Golovachev, op. cit., p. 73.

[37] Ibid.

[38] Ibid.

[39] Not to be confused with leading institutes, which administer research projects undertaken jointly by several organizations.

[40] Amann et al., op. cit., p. 448.

during the 1959-1965 period, particularly with regard to its status vis-à-vis Western computer technology. This fact was demonstrated when the Soviet government employed the tactic of withholding the Lenin Prize as a mechanism for intervention. Lebedev's design team was nominated for the Lenin Prize for their work on the M-20, at that time (1957-1959) the best Soviet computer. However, the Prize was denied them "on the grounds that it represented no advances in the state of the art when foreign technology was considered."[41]

As a more positive incentive for the development of computer technology, Viktor M. Glushkov, the Director of the Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR in Kiev, was awarded a Lenin Prize in 1964 for his work in the theory of digital computers.[42]

There was reason for the Soviets to be concerned about the development of their computer industry relative to that in other Western countries. In 1960, the Soviet Union is estimated to have had about 500 computers in operation. This seems a small number compared with the approximately 5000 U.S. computers in operation at that time, but the Soviets were still in second place behind the United States. By 1965, the Soviet Union had about 1000 computers, but this number was already surpassed by France, West Germany, the United Kingdom, and Japan, putting the Russians in sixth place.[43] Since all of these countries have smaller populations than does the USSR, it is clear that the Soviet Union was slipping behind other developed countries in meeting domestic demand for computers.

DIRECT INTERVENTION, 1966-1968

By 1966, the introduction of computer technology and automated control systems into the national economy was more widely recognized,

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[41] Wade B. Holland, "The BESM and M-20 Series of Computers," *Soviet Cybernetics: Recent News Items*, No. 4, May 1967, p. 13.

[42] Wade B. Holland, "Analysis" accompanying A. Tikhonov, "The World Acclaimed 'Mir-1'," translated in *Soviet Cybernetics: Recent News Items*, No. 23, November 1968, p. 45.

[43] Bohdan O. Szuprowicz, "Eastern Europe's Thirst for Computers," *Computer Decisions*, November 1973, p. 23.

and the Central Committee of the CPSU and the Council of Ministers of the USSR became increasingly concerned about the state of the Soviet computer industry, characterized in one article as a "patchwork empire."[44]

Directives for the 1966-1970 Five-Year Plan approved by the Twenty-third CPSU Congress in April 1966 gave official recognition to the Soviet's concern about their computer industry. The Congress considered it essential "to raise the effectiveness of production on the basis of technical progress," and for this purpose to provide in the new Five-Year Plan for accelerating the growth of labor productivity through the integrated mechanization and automation of production. It was also considered essential to provide for "wide use of electronic computers in planning the national economy and in managing production, in transport, trade and scientific research."[45] (It is interesting to note that the latter phrase did not appear in the Central Committee's draft of the Directives published on February 20, 1966, but appeared in boldface type in the Directives approved in April.) Another essential task was "to apply modern computer technology" in order "to improve the guidance of the country's economy."[46]

Specific tasks involving computer technology were assigned to certain sectors of the economy. In industry it was necessary

> To pay special attention to the need for a considerable increase in the manufacture of instruments and means of automation, for a broadening of their assortment and for an improvement in their technical level. To substantially increase the output of semi-conductor instruments.
> To substantially expand the production of computers and programming machines and the output of business machines and machines for the mechanization and automation of computation work, bookkeeping and accounting.[47]

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[44]Golovachev, op. cit.

[45]"Congress Directives for Five-Year Plan as Adopted," *The Current Digest of the Soviet Press*, Vol. 18, No. 16, May 11, 1966, p. 4.

[46]Ibid., p. 8.

[47]Ibid., p. 5.

In transport and communications, one of the basic tasks was "to introduce automatic equipment and computers more extensively."[48] In capital construction, one of the stated goals was "to introduce more broadly in construction the use of grid methods of planning and administration based on computer technology."[49]

Besides expanding domestic production, including that of computers, Soviet industry was directed "to make the greatest possible use of the advanced scientific and technological achievements of foreign countries, while developing international technical cooperation."[50] As a more general requirement, to raise the effectiveness of production throughout the Soviet economy, it would be necessary "to make wider use of the advantages of *the socialist international division of labor* and foreign trade."[51] These envisioned expanded economic relations with foreign countries were also to include "a considerable expansion of trade with foreign countries in patents and licences."[52]

Thus the intentions of the April 1966 Party Directives appear to go beyond simply acknowledging the rising priority of the Soviet computer industry and a need to apply its products in various sectors of the economy. The tasks called for were obviously intended to lay the groundwork for filling in the gaps in the Soviet computer industry through the expansion of foreign trade, the exchange of technical information by means of patents and licenses, and through technical and trade agreements in the area of computer technology with the CEMA countries. (The last item is discussed in more detail under "Centralizing Forces, 1969-1974," below.)

Also in April of 1966, the Party and the government adopted a resolution specifically aimed at solving the problem of proper division of responsibilities among the various agencies concerned with

[48] Ibid., p. 11.

[49] Ibid., p. 12.

[50] Ibid., p. 6.

[51] Ibid., p. 5. Italic indicates boldface type in Russian original.

[52] Ibid., p. 19.

computer technology. The resolution gave Gosplan responsibility for "aggregate production planning for all forms of computer technology, and the distribution of general-purpose electronic computing, data-processing, and control computing machines."[53] Design and production "of all forms of computer technology were . . . divided between the Ministry of the Radio Industry and the Ministry of Instrument Building, Means of Automation, and Control Systems [Minpribor]. . . ."[54] The State Committee on Science and Technology of the Council of Ministers of the USSR was charged with developing the basic trends in computer technology and automated control systems.[55] The Academy of Sciences was instructed to concentrate on the theoretical problems of "a unified system of optimal planning, calculation, and control in the various sectors of the national economy, particularly on the development of mathematical methods and algorithms for solving economic problems."[56] Recommendations for the training of computer specialists were to be made by Gosplan, the Ministry of Higher and Secondary Specialized Education, and other interested agencies.[57]

More specifically, the Ministry of the Radio Industry was made responsible for developing general-purpose computers for control systems, and for developing input, output, and storage devices. It was also to provide the means "for assembly, debugging, installation, and repair of all computer hardware and auxiliary devices which it produces."[58] Minpribor was made responsible for "the development and production of control and specialized machines, programmed devices, and other automation hardware for . . . control systems for technological

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[53] V. I. Loskutov, "Vnedrenie v narodnoe khoziaystvo sredstv vychislitel'noi tekhniki i avtomatizirovannykh sistem upravleniia" ["The Introduction of Computer Hardware and Automated Control Systems into the National Economy"]; excerpts translated in *Soviet Cybernetics: Recent News Items*, No. 1, February 1967, p. 51.

[54] Ibid., p. 52.

[55] Ibid., pp. 52-53.

[56] Ibid., p. 53.

[57] Ibid., p. 29.

[58] Ibid., p. 56.

processes."[59] Minpribor was also charged with supervising territorial design-installation offices to develop automated control system projects, attach them to appropriate enterprises, assemble, debug, install, and subsequently repair such systems. Both ministries were "obliged to provide their machines with libraries of standard programs, autocodes, and algorithmic-language translators."[60] They were also instructed to take measures to lower the cost of their products.[61]

The April 1966 resolution, for the first time, made specific Soviet agencies responsible for developing and introducing a unified system of state standards for computer hardware to be used in the planning, accounting, and control functions of the Soviet economy. The agencies charged with this task included the Committee on Standards, Measures, and Measuring Devices under the Council of Ministers of the USSR, Gosplan, the Central Statistical Administration of the USSR, and "interested ministries and agencies."[62]

Although these instructions seemed clear enough, later evidence indicated that they were not carried out in full. Apparently, such a directive from the Soviet Party and government did not carry enough weight to abolish, totally, the negative effects of ministerial parochial interests and jealousies.

Other administrative measures were taken that would have a direct effect on the Soviet computer industry. As of January 1967, Minpribor became the first Soviet ministry to operate all of its enterprises, "with the exception of its experimental and testing enterprises,"[63] according to the new system of planning and economic incentives. The principles of the new system of economic management were worked out by the September 1965 plenary session of the CPSU Central Committee, and implementation of the changes were begun at a small number of

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[59] Ibid., p. 56.

[60] Ibid., p. 53.

[61] Ibid., p. 56.

[62] Ibid., p. 54.

[63] "What's New in Industry: Accelerator of Progress," *Izvestiia*, April 1, 1967, p. 1; translated in *The Current Digest of the Soviet Press*, Vol. 19, No. 13, April 19, 1967, p. 35.

enterprises in 1966. The central task of the economic reform was "to establish the proper balance between centralized planning and the independence of economic units."[64] Under this new system, enterprises would be able to make their own decisions in many areas of production development--decisions formerly made from above--using price as their main economic guideline.[65] The new system was said to be less rigid than the old because

> the center does not issue directives to all the agencies down the line (as was formerly the case when the technical, industrial and financial plan was approved). This is a flexible system because it allows centralized decisions only with regard to links which are in direct reciprocal subordination (branch administration and ministry, factory and chief administration, etc.).[66]

It was hoped that these new measures would stimulate greater productivity through greater participation in planning by enterprises. Unfortunately, figures or other indicators of the effect of these measures on the Soviet computer industry were not available to the author.

In carrying out the Directives of the Twenty-third CPSU Congress, the State Plan for Development of the USSR National Economy for 1967 specified that Soviet computer technology was to be increased by more than 24 percent.[67] The 1967 State Plan also required that 57 automated systems based on computers, 85 information-computer centers, and 59 computer centers be introduced into the economy.[68]

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[64] N. Federenko, "The Reform in Industry: Initial Results and Problems of Increasing Its Efficacy," *Planovoye khozyaistvo*, No. 4, April 1967, pp. 5-17; translated in *The Current Digest of the Soviet Press*, Vol. 19, No. 19, May 31, 1967, p. 7.

[65] Ibid., p. 8.

[66] Ibid.

[67] "On the State Plan for Development of the USSR National Economy for 1967: A Report by N. K. Baibakov, Vice-Chairman of the USSR Council of Ministers and Chairman of the USSR State Planning Committee," *Pravda*, December 16, 1966, pp. 1-5, and *Izvestiia*, December 16, 1966, pp. 2-4; translated in *The Current Digest of the Soviet Press*, Vol. 8, No. 52, January 18, 1967, p. 5.

[68] Ibid., p. 6.

In April 1967, the planning procedure for research work funding was changed, giving heads of research institutes greater independence in the organization of work and in the expenditure of research funds. Under the new system, only total funding and the wage fund were to be regulated from above for those institutes engaged in work planned by the State Committee for Science and Technology. Such a procedure would permit the heads of research institutes to determine the structure of the institute and the number of personnel and their wage rates. Directors of research institutes could also decide on the amount of funds to be spent for individual items within their own estimates of administrative and managerial expenditures.[69]

Also in April 1967, a new economic incentive, the Mark of Quality, was adopted by the Committee of Standards, Measures, and Measuring Devices under the Council of Ministers of the USSR. The Mark of Quality was intended to be awarded for a period of 1 to 3 years to products of high quality that exceeded state standard specifications.[70] Subsequently, the Mark of Quality was awarded to the Minsk-32.

The various domestic measures taken to improve the Soviet computer industry were apparently insufficient, however. Almost a year after the April 1966 resolution, a Soviet engineer complained that "computer technology has no one master."[71] Instead, it is still divided among various ministries, each with "its own viewpoint and its own technical policies for its factories, scientific research institutes and computer engineering design bureaus. Quite often, inexplicable parallelism and overlap are noted, and the same elements, circuits, components, and even machines are created in different jurisdictions."[72] Golovachev mentions in particular Minpribor, the Ministry of the Radio Industry, the Ministry of the Electrical Engineering Industry, the Central Statistical Administration of the USSR, and the State Committee on

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[69] Ibid.

[70] "Znak kachestva," ["Mark of Quality"], *Pravda*, April 8, 1967, p. 4.

[71] Golovachev, op. cit., p. 71.

[72] Ibid., p. 72.

Science and Technology of the Council of Ministers of the USSR. More specifically:

> Many scientific research institutes have been transferred to the Ministry of the Radio Industry of the USSR. Therefore, no small number of enterprises under the supervision of the Ministry of Instrument Construction have found themselves without scientific guidance. This is why these enterprises have begun to create their own design bureaus and scientific research institutes. There is a diffusion of forces and funds, and "parallel" design bureaus and institutes multiply. . . .[73]

Presumably Golovachev is referring to research institutes formerly under the control of the Academy of Sciences system. This would help to explain why, in general, the research institutes under Minpribor have been created more recently than those under the Ministry of the Radio Industry. Golovachev advocates the formation of "a special ministry of computer and organizational technology" that would develop a centralized technological policy and assume responsibility for its implementation.[74]

In July 1967, O. Aven, a Senior Scientific Associate of the Institute of Automation and Remote Control, wrote: "For Soviet specialists there are not now any complex technical secrets which would hinder the intensive development of computer technology and its efficient use. The majority of our shortcomings in this area have been caused by organizational ambiguity."[75] According to Aven, a major problem of Soviet computer technology is that "In practice there is not any single technical policy,"[76] even though "the necessity for a single technical policy in the production of computer hardware is becoming more and more

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[73]Ibid., p. 73.

[74]Ibid., p. 77.

[75]O. Aven, "EVM pred'yavlyaet schet" ["The Computer Gives an Accounting"], *Pravda,* July 1, 1967, p. 2; translated in *Soviet Cybernetics: Recent News Items,* No. 8, September 1967, p. 16.

[76]Ibid.

obvious."[77] In his opinion, such a necessity "requires the centralization of production."[78]

No doubt prompted in part by its awareness of the continuing shortcomings in the industry, the Soviet government, in 1967, took steps to improve conditions for increasing the number of Soviet licenses purchased abroad. Licensing was not widely used before this time as a vehicle for filling in the gaps in the Soviet technical capability "because of the conservative notions of many designers, producers, and economists who did not want to understand how important and mutually beneficial international scientific and technical exchanges are."[79] To remedy this situation, the Council of Ministers of the USSR adopted a resolution delineating the responsibilities of various government agencies for patents and licenses. Responsibility for the acquisition of foreign licenses and for control over their use in the Soviet Union, as well as over the sale of licenses for Soviet inventions, was given to the State Committee on Science and Technology.[80]

The Soviet government also took steps to increase its importation of foreign computers. On March 3, 1967, the Soviets signed a 5-year agreement with the British "Plessey Co. Ltd.," which provided for joint research in electronics, automation, and computer engineering.[81]

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[77] Ibid., p. 17.

[78] Ibid.

[79] "Dal'nyaya doroga otkrytij" ["The Long Road of Invention"], *Izvestiia*, August 3, 1967, p. 2; translated and summarized in *Soviet Cybernetics: Recent News Items*, No. 8, September 1967, p. 104.

[80] "O merakh po uluchsheniyu patentno-litsenzionnoj raboty v strane" ["On Measures To Improve the Patenting and Licensing Work in the Country"], *Ekonomicheskaya gazeta*, No. 33, August 1967, p. 5; translated and summarized in *Soviet Cybernetics*, No. 8, September 1967, p. 112.

[81] "Scientific and Engineering Agreement," *Moscow News*, No. 10, March 1967, p. 7.

CENTRALIZING FORCES, 1969-1974

The Soviet government's use of various mechanisms to accelerate the progress of the computer industry apparently fell considerably short of official expectations. These measures, even when effective, constituted only partial solutions to an exceedingly complex problem. If the Soviet Union were to have a computer industry to serve its own needs, not to mention one with which to compete in world markets, much more drastic measures were necessary. On its own, the industry continued to fall far short of the domestic demands for computers envisioned by the Twenty-third CPSU Congress, and there was a great danger that at the established rate of progress, the shortfall would become even more embarrassing as the years went on.

The R&D leaders in the computer field had their own views about what should be done to remedy the situation, quite independent of the Party-government approach. Academician V. M. Glushkov advocated bypassing all R&D on third-generation computers and directing R&D efforts toward developing fourth-generation computers.[82] Otherwise, he contended, Soviet computer development would never catch up with the world computer industry. He did not explain, however, how it would be possible to create fourth-generation computers without having mastered the technical requirements of third-generation computers. Academician Lebedev seemed absorbed in a follow-on to his own successful BESM-6 (a scientific computer as distinguished from a data-processing computer), but not particularly tuned in to the problems of the Soviet computer industry as a whole. Most leading R&D specialists seemed more interested in empire-building, or in protecting the empires they had already built, than in working toward broad, practical solutions to the problems created by the fragmentation of the industry. Some limited cooperation between certain research institutes and production facilities had begun by this time, such as the collaboration of the Institute of Cybernetics in Kiev with the Kiev Electronic Computer and Control Machines (VUM) Plant and the Severodonetsk Scientific Research Institute of Control Computers with the Severodonetsk Instrument Construction

[82] See footnote 7 on p. 28.

Plant,[83] but it appears that overall coordination in R&D effort was reluctant and almost nonexistent.

By the end of 1969, some of the other socialist countries with developed electronics industries, particularly the German Democratic Republic and Poland, were beginning to show signs of developing computer industries that could compete at least with the Soviet computer industry, if not on the world market. M. Rakovskij, who was Deputy Director of Gosplan as well as the Permanent Chairman of the Intergovernmental Commission on Collaboration of Socialist Countries in the Area of Computer Technology, later acknowledged that the Soviet Union had been very well aware of the achievements of other socialist countries at that time. He stated that the Robotron system of the German Democratic Republic, the ODRA series of Poland, the Tesla machines of Czechoslovakia, and the Elka keyboard calculators of Bulgaria were all widely known.[84]

Thus, by late 1969, the Soviets faced the possibility of being overshadowed in the computer field by some of their own Eastern European neighbors. Some of those countries, particularly Czechoslovakia,[85] were also beginning to look to the West rather than to the Soviet Union to fill in the gaps in their computer industries, an undesirable trend from the Soviet point of view. At the same time, the Soviet Union was suffering from lags in its own computer industry, as well as from a seriously uncoordinated R&D effort and a dispersed technical policy. These considerations appear to have motivated the Soviet government to sign, in December 1969, a multilateral agreement and separate bilateral agreements with the governments of Bulgaria, Czechoslovakia, the German Democratic Republic, Hungary, and Poland for the development

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[83] For further details, see the discussion in Section IV under the headings "Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR" and "Severodonetsk Scientific Research Institute of Control Computers."

[84] M. Rakovskij, "Six ES Computers Displayed in Moscow," *Soviet Cybernetics Review*, Vol. 3, No. 4, July 1973, p. 8.

[85] Wade B. Holland, "Political Climate Affects Czech Computer Industry," *Soviet Cybernetics Review*, Vol. 1, No. 2, March 1972, pp. 7-8.

and production of a new line of computers to be known as Ryad ("series" in Russian). These computers are designated by the Russian acronym for Unified System, "ES." According to Wade Holland, the actual decision on the part of the Soviets to build Ryad took place as early as 1965, but whether this decision included an intergovernmental arrangement is not clear. In any case, this decision was not formalized until the 1969 agreement.

The Ryad effort is administered through the Intergovernmental Commission on Collaboration of Socialist Countries in the Area of Computer Technology. The Intergovernmental Commission was set up to carry out the goals of the complex program adopted by the Council on Mutual Aid at its 25th Session. As mentioned above, the Permanent Chairman of the Intergovernmental Commission is a Soviet, M. Rakovskij, who, as Deputy Director of Gosplan, has the potential to be influential in the future direction of the Soviet computer industry. The administrative machinery of the Intergovernmental Commission includes:

> The Council of Chief Designers, made up of representatives from each country, who carry out design and scientific duties; The Automated Management Systems Group, which is implementing a coordinated policy for introducing ES (Unified System) computers into the national economies of the member nations; The Coordinating Center, which monitors the execution of all resolutions adopted by the Intergovernmental Commission.[86]

The Intergovernmental Commission also formed an Economic Council for "conducting work in intensifying specialization and joint operation of new computer production; preparing substantive technical and economic documents for such specialization; and coordinating these plans.[87]

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[86] M. Rakovskij, "International Framework of ES Development," translation of excerpts from "Upravlenie i kibernetika" ["Control and Cybernetics"], *Pravda*, May 31, 1973, p. 4; in *Soviet Cybernetics Review*, Vol. 3, No. 5, September 1973, pp. 47-48.

[87] Ibid., p. 48.

According to the multilateral agreement, the Soviet Union bears the basic responsibility for design and coordination of the Ryad system, as well as for development of basic circuits, central processing units (CPUs), and most software, including operating systems.[88]

The Soviet Union, the German Democratic Republic, Poland, and Czechoslovakia are all contributing peripheral equipment, but Czechoslovakia is mainly responsible for integrated circuits. Some CPUs for the smaller machines are to be produced by Poland and Hungary. Rumania was originally to have manufactured minor subcomponents and software, but withdrew completely from the program very early and has since established relations with Western computer manufacturers.[89] Cuba was later added as a member of the agreement, but probably as a "favored nation" trading partner rather than as a producer of computers.[90]

The bilateral agreements, also signed in December 1969, are believed to be mostly with the USSR and other bloc countries, giving the USSR even greater control over the project than does the multilateral agreement alone. Some of these agreements "obligate East European factories to supply components to Soviet factories."[91] Other bilateral agreements probably regulate the sales of the machines produced, particularly by the Soviet Union to the other Eastern European countries.

Over 100 organizations and enterprises in the cooperating countries were said to have participated in the development of the Unified System.[92] In the spring of 1973, Rakovskij stated that "more than 20,000

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[88] Wade B. Holland, "Ryad Details Begin To Emerge," *Soviet Cybernetics Review*, Vol. 2, No. 2, March 1972, p. 19.

[89] *SCR* Commentary to M. Rakovskij, "International Framework of ES Development," translation of excerpts from "Upravlenie i kibernetika" ["Control and Cybernetics"], *Pravda*, May 31, 1973, p. 4; in *Soviet Cybernetics Review*, Vol. 3, No. 5, September 1973, p. 51.

[90] Ibid.

[91] Ibid.

[92] Rakovskij, "Six ES Computers Displayed in Moscow," op. cit., p. 10.

scientific workers and designers are continuing to work on the development of computer hardware. More than 70 plants, with some 300,000 workers, are engaged in the production of hardware."[93]

The Ryad decision has a number of interesting aspects. First of all, the series is closely modeled after the IBM System/360, and the Soviets themselves have said that the ES machines will be program compatible with the IBM 360 series. This strongly indicates that the Soviets, who only recently have begun to realize the overriding importance of software in the development and use of computers, are trying to avoid the enormous time and money investment needed for the software of a newly designed, modern computer system. Software has been and continues to be a major weakness in the Soviet industry that would not be easily corrected even by extensive reorganization or tightening up measures. Another bonus would be that the Soviet machines could use American-developed computer programs without having to reprogram.

Second, the largest units in the system, the ES-1050 and the ES-1060, were scheduled to be both developed and produced by the Soviet Union itself.[94] Joint development and production were planned for two of the medium-sized machines. The ES-1020 was developed jointly by the Design Bureau of the Minsk Ordzhonikidze Factory and Bulgarian specialists in 1971, and subsequently went into production at the Minsk Ordzhonikidze Computer Factory (home of the successful Minsk line of computers) and at the Brest Electromechanical Plant in the Soviet Union. Production was also scheduled for Bulgaria, but has not been verified.[95] The other medium-sized machine, the ES-1030, was designed at the Erevan Scientific Research Institute of Mathematical Machines of the Academy of Sciences of the Armenian SSR. It went into production at the Erevan Elektron Plant in 1972. The Polish version of the ES-1030 was to be produced by the MERA Association in

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[93] Rakovskij, "International Framework of ES Development," op. cit., p. 48.

[94] "Description of ES Units," *Soviet Cybernetics Review*, Vol. 4, No. 3, May/June 1974, pp. 14-16.

[95] Ibid., pp. 9-10.

Poland, which reportedly was having difficulties with getting that unit into production.[96]

Other machines in the series have been developed and produced by some Eastern European countries on their own. The smallest machine in the series, the ES-1010, has been both developed and produced by Hungary. It has been serially produced by the Videotron Factory since 1972.[97] The ES-1021, also called the ES-1020A, a medium-sized specialized machine, was developed at the Czech Research Institute of Mathematical Machines. Although a prototype was reported to have been tested successfully in 1972, it is not known to be in production.[98] The third machine to be developed and produced independent of the Soviet Union is the ES-1040, designed by the German Democratic Republic. The ES-1040 is the largest of the medium-productivity machines in the series. It has been produced by the Robotron Enterprise in the German Democratic Republic since 1973.[99]

Control of the development and production of the two high-productivity machines in the series, the ES-1050 and the ES-1060, has been retained by the Soviet Union. The ES-1050 (described as being equivalent to an IBM 360/65) is being manufactured at the Penza Calculating and Analytical Machines (SAM) Plant, which earlier produced the widely used Ural line of computers. Production of the machine probably began around 1973.[100] The ES-1060, although under development in the Soviet Union, has not yet been officially announced. It is scheduled for exclusive production in the Soviet Union. An operating speed of 3 million operations per second was originally planned for the ES-1060, but recent private reports indicate that the actual speed will be around 1.5 million operations per second.[101]

The third interesting aspect is that all the work done on the

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[96] Ibid., p. 12.

[97] Ibid., p. 9.

[98] Ibid., p. 11.

[99] Ibid., p. 13.

[100] Ibid., pp. 14-15.

[101] Ibid., p. 16.

Ryad machines within the Soviet Union is being conducted at facilities under the Ministry of the Radio Industry, one of the two major ministries already producing computers. Deputy Minister of the Radio Industry, V. D. Kalmykov, announced the first details of the Ryad line,[102] which would seem to indicate a special prominence for the Ministry of the Radio Industry in the future development of the Soviet computer industry.

A fourth point of interest is the extent to which work on the Ryad machines has supplanted other activities at existing Soviet R&D and production facilities. Minsk, Penza, and Erevan, all producers of earlier successful lines of computers, are involved in the production of Ryad machines. Brest, the fourth production site, seems to be a fairly new plant that has manufactured at least one piece of peripheral equipment in the past but which is now known to have produced any computers before Ryad. In the case of the Minsk Ordzhonikidze Computer Factory, production of the Minsk-32 has continued at a rate of 500 to 600 units per year, even while the ES-1020 is being produced.[103] Production of the Nairi-3 machine seems to have been moved in 1973 from the Erevan Elektron Factory to the Baku Radio Factory to make room for the production of the ES-1030.[104] At the Penza Calculating and Analytical Machines (SAM) Plant, it is not clear whether production of the large ES-1050 has supplanted that of the Ural-16, the most advanced machine in the Ural series.

It is more difficult to pin down the extent to which the Soviet R&D facilities are involved in the Ryad work. According to the multilateral agreement, development policies and design decisions are to be made by the Council of Chief Designers under the Intergovernmental Commission. Actual design work has been done at the Design Bureau of the Minsk Ordzhonikidze Computer Factory (ES-1020) and at the Erevan

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[102] "Ryad Details Emerge," *Soviet Cybernetics Review*, Vol. 2, No. 3, May 1972, p. 5.

[103] Wade B. Holland, "Unwrapping the ES Computers," *Soviet Cybernetics Review*, Vol. 3, No. 5, September 1973, p. 17.

[104] "Nairi-3 in Production Checkout," *Soviet Cybernetics Review*, Vol. 3, No. 3, May 1973, p. 30.

Scientific Research Institute of Mathematical Machines (ES-1030). However, at the same time that the ES-1020 was being readied for production, the Minsk-32 was being modernized,[105] but work on a follow-on to the Nairi series of computers did not stop[106] even though the Erevan Institute also designed the ES-1030.[107] It is possible that some or all of the ES-1050 design work was done by the Design Bureau of the Penza SAM Plant.

Two of the most important computer research institutes have not yet been officially involved with Ryad. Academician V. M. Glushkov, Director of the Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR, has disavowed any connection of his institute with the Ryad work and has even published criticisms of the ES machines with respect to their cost, the way in which the production of their peripherals is organized, and the lack of provision for compatibility with the Minsk machines at the data-gathering and external-storage levels.[108] Several years ago, reports also indicated that Academician S. A. Lebedev of the Institute of Precise Mechanics and Computer Engineering (under the joint control of the USSR Academy of Sciences and of the Ministry of the Radio Industry) also refused to be involved with Ryad.[109] Lebedev has not announced any new machines since the development of the BESM-6 in 1965, but rumors about a BESM-8 have persisted. In 1972, rumors also began about a separately developed super Ryad model, designated the ES-2000. It was speculated at that time that the long-awaited BESM-8 might evolve into the ES-2000.

Apart from the importance of the work of their respective research institutes, Glushkov and Lebedev are considered two of the major spokesmen for the Soviet computer industry. If the Party-government cannot

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[105] V. M. Glushkov, "Preemstvennost' pokolenii EVM" ["The Continuity of Computer Generations"], *Ekonomicheskaya gazeta*, No. 24, 1972, p. 7.

[106] "Nairi Follow-on," *Soviet Cybernetics Review*, Vol. 3, No. 4, July 1973, p. 5.

[107] "Ryad-30 Announced," *Soviet Cybernetics Review*, Vol. 2, No. 4, July 1972, p. 5.

[108] Glushkov, "Preemstvennost' pokolenii EVM," op. cit.

[109] Holland, "Ryad Details Begin To Emerge," op. cit., pp. 18-19.

succeed in persuading most of the key figures in Soviet computer development to cooperate on the Ryad project, the work may turn out to be another competitive effort instead of the unifying force it was intended to be.

Perhaps even more important, some of the deficiencies that have been reported in the development and production of the Ryad machines also occurred in the development and production of earlier Soviet computers. For example, production of the ES-1020 computer began before the developers of the software had a unit to work with.[110] According to Glushkov, some of the mistakes made during the development of operating systems for the ES computers could have been avoided by considering the needs of the consumer, in this case the developers of automated management systems.[111] If the old, narrow perceptions and habits of handling computer development and production persist, no amount of bureaucratic reorganization will solve the basic problems originally arising from the fragmentation of the Soviet computer industry. Even if the hardware and software problems of Ryad are solved more satisfactorily than has been the case with previous Soviet computers, it is difficult to comprehend how the Ryad machines could be used any more effectively than their predecessors if better provisions are not made for development of computer systems, installation, maintenance, and trained operating personnel.

Not to be outdone by the Ministry of the Radio Industry, Minpribor announced, in 1969, its own series of third-generation computers, the ASVT or Modular System of Computer Hardware. The ASVT line is not strictly competitive with the Ryad line, since the Ryads are generally larger, general-purpose machines, whereas the ASVT are smaller and are oriented toward more specific purposes, particularly process control. The ASVT computers are intended for use in industry, transport, science (mainly in the processing of information), and consumer services.

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[110] M. Korolev, "Sem' nyanёk vokrug EVM" ["Seven Nannies Around a Computer"], *Pravda*, October 9, 1972, p. 2.

[111] Glushkov, "Preemstvennost' pokolenii EVM," op. cit.

According to one journal, "the ASVT system guarantees a unified technical policy in the design of automated control systems."[112]

At some point after the original announcements of the new series, but in any event by 1971, it was conceded that some machines in the ASVT line, designated the ASVT-D, were actually based on discrete elements and were therefore only second-generation machines. It was contended, however, that their "structure and architecture are on the level of the best foreign third-generation machines.[113] The ASVT-D models include the M-1000, M-1010, M-2000, and M-3000 central processors. The M-1000 and the M-1010 are special-purpose processors, and the M-2000 and M-3000 are general-purpose processors.

The ASVT-M models are based on microelectronics and hence are third-generation machines in the series. They include the M-40, M-400, M-4030, M-5000, and M-6000. The M-4000, the key model in the ASVT-M series, has been produced at the Kiev Electronic Computer and Central Machines (VUM) Plant since 1972. The M-4000 can be linked not only to other ASVT devices, but also "to ES computers having standard connections."[114] The M-5000, a small data-processing computer, has been produced at the Vilnius Calculating Machines Plant since 1972. The M-6000 is described as a minimachine, and was to have been put into production at unidentified factories under Minpribor sometime during 1973.

The M-4030 computer, the most powerful ASVT machine, has some characteristics that have led to speculation that it may be a link between the ASVT-M series and the Ryad line. It is program compatible

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[112] "New Facilities Added to ASVT Line," translation of excerpts from a series of articles in *Mekhanizatsiya i avtomatizatsiya upravleniya* [*Mechanization and Automation of Control*], No. 4, 1971, pp. 23-53; in *Soviet Cybernetics Review*, Vol. 2, No. 4, July 1972, p. 18.

[113] Ibid.

[114] A. I. Grinshin, "Process Control: Retooling for ASVT Production," translation of excerpts from "Novye sredstva upravlyayushchej vychislitel'noj tekhniki" ["New Techniques for Control Computer Technology"], *Pribory i sistemy upravleniya* [*Instruments and Control Systems*], No. 3, 1973, pp. 16-17; in *Soviet Cybernetics Review*, Vol. 4, No. 1, January/February 1974, p. 19.

not only with the M-2000 and M-3000 of the ASVT-D series, and with the M-4000 of the ASVT-M series, but also with the Ryad ES-1020 and ES-1030 computers. The architecture, hardware design, and software of the M-4030 is based on those of the ES computers. The M-4030 uses ES discs, tapes, printer, card reader, and card output punch, but its other peripheral devices form a new, previously unknown series. The State System of Instruments has designated the M-4030 a principle machine for automated control systems, unlike the other M machines.[115]

Production of the ASVT-M line was accelerated by Minpribor in 1973. Some 600,000 rubles from state funds were allocated to the Kiev Electronic Computer and Control Machines (VUM) Plant by the Soyuzelektronschetmash All-Union Industrial Association to speed up retooling for production of the ASVT-M computers.[116]

The ASVT effort, unlike that of Ryad, appears to be solely a Soviet undertaking, since no mention has been made of it in Council of Mutual Economic Aid (CMEA) announcements. Although some of the Ryad machines are also designed for application in process control, it would appear that the ASVT is intended to supplement their capabilities in the wide range of special conditions existing in the Soviet economy.

AN OVERVIEW OF THE PRESENT STATE OF THE SOVIET COMPUTER INDUSTRY

To understand the present state of the Soviet computer industry, it is essential to know what went before, since many of the basic characteristics of Soviet R&D and production have not changed radically. The Soviet computer industry is in a transition phase, however, and the changes currently planned for it will no doubt be much more visible 10 years from now. Now, only a small amount of the total production effort is going into third-generation machines; many second-generation machines are still being produced. The Soviet government is attempting to centralize the industry through the Ryad and ASVT

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[115]Wade B. Holland, "Process Control: M-4030 Computer Links ASVT to ES," *Soviet Cybernetics Review*, Vol. 4, No. 1, January/February 1974, p. 13.

[116]"Funds for Computer Plant," *Soviet Cybernetics Review*, Vol. 4, No. 1, January/February 1974, p. 5.

series, but at least one third-generation machine outside of these two series is scheduled for an independent follow-on: the Nairi-3. At least one major computer developer, Academician V. M. Glushkov, and many minor ones do not yet appear to be involved in the Ryad and ASVT work. Whether this generation of computer developers will ever be completely absorbed into the government's plans is open to question.

Looking to the future, it is very important to put the Soviet government's grandiose plans into proper perspective. Twelve to fifteen thousand Ryad machines were scheduled for production in the current (ninth) Five-Year Plan (1971-1975), but it is highly doubtful that anywhere near that number will be produced by 1975. The first models were not put into production until 1972, and only a few units were installed by 1973. There were considerable delays in the Ryad development work, many of them due to the same conditions that caused delays in earlier Soviet computer work. Until these basic conditions are changed at both the research-institute and production-enterprise levels, the present managerial system will continue to diminish or nullify the effectiveness of otherwise viable designs.

At this point it seems appropriate to note that under the socialist system, the facilities of five industrially developed countries are needed to do what one American company achieved by itself. In all fairness, it must be admitted that the American firm achieved its goals over a longer period than is planned for the socialist countries. On the other hand, the American company was breaking ground at the time, and it should be easier for the socialist countries to follow the American lead. Whether or not they will achieve their goals remains to be seen.

IV. SOVIET COMPUTER RESEARCH AND DESIGN ORGANIZATIONS

The Soviet organizations that conduct research and produce designs for computers are subordinate to the USSR Academy of Sciences, a ministry--usually the Ministry of the Radio Industry or the Ministry of Instrument Construction, Means of Automation, and Control Systems (Minpribor)--or a particular computer plant, itself subordinate to one of the ministries. The oldest Soviet research and design institutes are generally under either the USSR Academy of Sciences or under one of its regional academies. The reason for this subordination is that the computer was originally the brainchild of academicians working on mathematical and technical problems, rather than the inspiration of industrialists aiming for greater efficiency. At least the organizations under the Academy of Sciences seem to have a great deal of latitude in deciding what they will research and design, once they have received their funding, although this situation may change as control over the Soviet computer industry becomes more centralized. The institutes under the ministries, and particularly those under the computer plants, may be assumed to be more constrained.

Scope of the work of the research institutes, and hence their organization, seems to vary widely. Some institutes concentrate on research, others on design, and some do both research and design. Likewise, the responsibilities of the design bureaus seem to vary according to the organization to which they are attached. In general, it appears that design bureaus subordinate to strong research institutes function at a low level of design, perhaps preparing the already developed computer for production. A design bureau attached to a production facility may also help to debug a developed computer or prepare it for manufacture. In at least two instances, design groups attached to production facilities (the Design Bureau of the Minsk Ordzhonikidze Computer Factory and the Design Bureau of the Penza SAM Plant) seem to have been themselves totally responsible for the development of a line of computers.

The division of labor with respect to hardware and software is

not clear cut. Originally, the institutes of the Academy of Sciences were overwhelmingly interested in producing hardware and left the software and the design of computer systems pretty much up to the customers. In some cases, existing organizations whose main purpose is not computer research but research in other fields (such as medicine) tried to fill in this gap, and continue to try. In other instances, a few new organizations sprang up to meet this need (for example, Andrei Ershov's Programming Section of the Novosibirsk Computer Center). Increasingly, the Soviet designers of hardware are beginning to appreciate (10 years behind the United States) that software must be developed simultaneously with the hardware in order to avoid long delays in the use of hardware and to get maximum value from it.

The remainder of this section discusses the main Soviet research and design institutes in terms of each institute's relationship to its governing ministry or organization and the manufacturing facilities. The discussion also covers the hardware and/or software developed by each institute, as well as other important research activities in specific areas of cybernetics.

INSTITUTES UNDER THE SOVIET ACADEMY OF SCIENCES SYSTEM

As noted above, some of the earliest work on computers in the Soviet Union was done in institutes under either the USSR Academy of Sciences or one of its regional academies. These institutes include: The Institute of Precise Mechanics and Computer Engineering of the USSR Academy of Sciences (Moscow); the Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR, which evolved in 1962 from the Computer Center of the Academy of Sciences of the Ukrainian SSR (Kiev); the Erevan Scientific Research Institute of Mathematical Machines of the Academy of Sciences of the Armenian SSR; and the Institute of Electronic Control Computers of the USSR Academy of Sciences (Moscow).

Institute of Precise Mechanics and Computer Engineering (Moscow)

One of the oldest institutes, the Institute of Precise Mechanics and Computer Engineering, was formed around 1948, under the leadership of Academician S. A. Lebedev. Between 1948 and 1951, Lebedev designed the Soviet Union's first electronic computer, the MESM, at the Computer Center in Kiev. (See Fig. 1.) After moving to Moscow, Lebedev designed the Soviet Union's first large computer, the BESM-1, which was completed around 1952. Only one unit is known to have been produced.

The Institute continued its work with the BESM-2, which began almost immediately after completion of its first product. "The prototype unit of the BESM-2 was assembled at the Computer Center of the Academy of Sciences, and engineers from the Center participated in its design."[1] The BESM-2 was not completed until early 1959, but was then produced and widely used in the Soviet Union. The BESMs were designed for scientific and engineering calculations.

An industrial machine, the M-20, was under development at the same time as the BESM-2. The M-20 was a joint design project by Lebedev, at the Institute of Precise Mechanics and Computer Engineering, and by M. K. Sulim, then at the Moscow Calculating Machines (SAM) Plant. The design of the M-20 is believed to have been completed around 1957, and it was in production by 1959 at the Moscow SAM Plant. Apparently the M-20 was produced in several places, particularly by NIISchetmash (Scientific Research Institute of Calculating Machine Construction), which is also located in Moscow.[2] Although the M-20 has been produced in fairly large numbers, reliability has been a problem with this machine.[3]

The M-220 was developed as the transistorized version of the M-20, but it is not known who was responsible for this work. Unofficially, some young engineers and technicians designed and built their

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[1] Wade B. Holland, "The BESM and M-20 Series of Computers," *Soviet Cybernetics: Recent News Items*, No. 4, May 1967, p. 7.

[2] Ibid., p. 13.

[3] Ibid., p. 18.

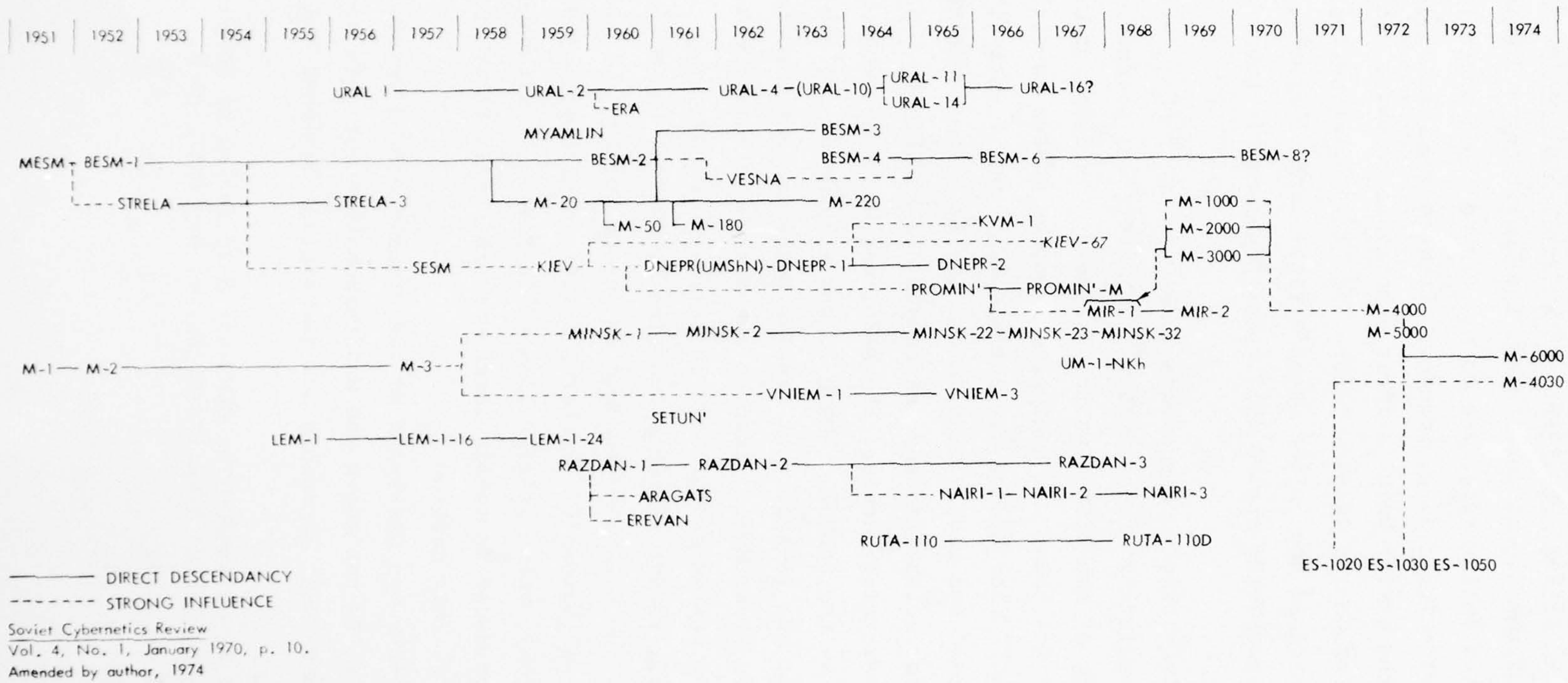

Fig. 1--Evolution of the Soviet computer: 1951-1974

own version of a transistorized M-20 at an unidentified plant in 1963.[4] This so-called "initiative" machine created a bureaucratic squabble that was resolved only when a state commission headed by Academician A. A. Dorodnitsyn, after testing and evaluating the machine, gave its official sanction. Further design and development of the machine was then taken over by Lebedev and his staff at the Institute of Precise Mechanics and Computer Engineering. The prototype of this machine was named the BESM-3. The production model, the BESM-4, has been manufactured in large numbers since 1964 and is being used widely in the Soviet Union.[5]

The leader of the opposition to the "initiative" machine was M. K. Sulim, who, as Deputy Chairman of the State Committee on Radioelectronics, issued an order prohibiting work on the machine as of March 30, 1964. (Actually, the machine had already been completed.) It is evident that Sulim and Lebedev disagreed in some way about the development of the M-220. It has been surmised that somehow Lebedev's work was subordinate to the State Committee on Radioelectronics, and that the "initiative" machine may have been Lebedev's means of bypassing the authority of the State Committee. Eventually the design of the "official" M-220 was completed, although behind schedule. Some units were manufactured beginning in 1965, but no details about it are known.[6]

The design of the BESM-6, still the Soviet Union's most important scientific and engineering computer, was completed and an operational configuration was available by 1966, when serial production began at the Moscow SAM Plant. Most of the group that had designed and developed the BESM-1 were involved with the design of the BESM-6, under Lebedev's leadership as the Chief Designer. "Many of the BESM-6 designers came to the Institute [of Precise Mechanics and Computer Engineering] as graduate students from the Moscow Power-Engineering

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[4] Ibid., pp. 19-20, 22.

[5] Ibid., pp. 20, 22.

[6] Ibid.

Institute, and did their thesis work on some phase of the BESM-1 design."[7] The BESM-6 is not compatible with any of its predecessors, neither with the three early BESMs (the one-of-a-kind BESM-1; the production model BESM-2; and the modified BESM-2, the BESM-2M), nor with the BESM-3, BESM-3M, and BESM-4--all transistorized versions of the M-20 computer. The BESM-6 is an all-solid-state machine with much greater computational power and much higher operating speeds than any of its predecessors.[8] In overall performance, the BESM-6 has been judged about 20 times faster than any previous machines.[9] Lebedev's group was awarded the State Prize in 1969 for the design and development of the BESM-6.[10]

Prior to the BESM-6, a few prototypes were constructed of another high-speed machine, the Vesna. The Vesna "was never serially produced because its design did not lend itself to economical mass production."[11] Because of some design features copied from the British Atlas computer, and the Vesna's similarity to the BESM-6, at least one American computer expert believes that it may have been "the product of Soviet efforts to reproduce a Western design far ahead of their own state of the art," and that it served as a model for the BESM-6.[12]

"Shortly after the announcement of the BESM-6 in 1965, L. N. Korolev, a designer under Lebedev, and N. A. Mel'nikov, Lebedev's second-in-command, indicated publicly that Lebedev's group was developing a follow-on model a full order of magnitude more powerful, incorporating many more advanced features, improved parallel operation, and more sophisticated multiprogramming capabilities. The goal of the project is to develop a machine comparable to the [American] CDC 6000

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[7]Wade B. Holland (comp.), "More on the BESM-6 Computer," *Soviet Cybernetics: Recent News Items*, No. 3, April 1967, p. 25.

[8]Ibid., p. 28.

[9]Wade B. Holland, "The BESM-6 Computer," *Soviet Cybernetics: Recent News Items*, No. 1, February 1967, p. 8.

[10]George Rudins, "Soviet Computers: A Historical Survey," *Soviet Cybernetics Review*, Vol. 4, No. 1, January 1970, pp. 16-17.

[11]Ibid., p. 19.

[12]Ibid.

series."[13] Rumors of a BESM-7 and a BESM-8 have persisted, but there is little evidence that such machines exist. There are also rumors that the BESM-8 may be destined to evolve into a super Ryad model, the Ryad 2000. If this is the case, the compatibility of the ES series will be open to question.[14]

Computer Center of the Academy of Sciences of the Ukrainian SSR (Kiev)

The first computer in the Soviet Union, the MESM (an acronym for "small electronic calculating machine"), was designed by a group in Kiev headed by Academician S. A. Lebedev. Work on the MESM began in 1948 and was completed in 1951. "After Lebedev's transfer to Moscow, the group served as a branch organization of the Institute of Precise Mechanics and Computer Engineering. In 1956, the group was organized into an independent Computer Center with Academician V. M. Glushkov as its head."[15]

A number of computers were designed in the Computer Center of the Academy of Sciences of the Ukrainian SSR beginning in 1957. These included the special-purpose, one-of-a-kind SESM computer (completed in 1957-1958) and the Kiev (1959), both intended for engineering calculations; in 1961, the Dnepr (also called the Dnipro [Ukrainian equivalent] and the UMShN), for engineering calculations and production control; and in 1962, the Promin', for engineering calculations. Other electronic machines developed at the Computer Center included the EMSS, intended for construction design, and the Iterator, used for calculations in combination with the MN-7, MPT-9, and other mathematical machines.[16] In addition, the Computer Center worked on developing a device for character recognition around 1961.[17]

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[13] Ibid.

[14] Wade B. Holland, "Ryad Details Begin To Emerge," *Soviet Cybernetics Review*, Vol. 2, No. 2, March 1972, pp. 18-19.

[15] Rudins, op. cit., p. 24.

[16] O. K. Nikolaenko, "The Development of Instrument Construction in the Ukraine During the 50 Years of Soviet Power," *Soviet Cybernetics: Recent News Items*, No. 9, October 1967, pp. 60-61.

[17] Patricia L. Stephan, "Soviet Research in Automatic Character Recognition: A Survey of Organizations," *Soviet Cybernetics: Recent News Items*, No. 3, April 1967, pp. 5-6.

In 1962, the Computer Center became the Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR.

Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR (Kiev)

The Institute of Cybernetics has been headed by Academician V. M. Glushkov ever since it was set up in 1962. It is a leading rather than a regular institute of the Academy of Sciences in that it has "responsibility for a particular research project (*tema*) for which work is being done by several organizations."[18] In this respect, it functions rather like a "research corporation," to use the terminology of some specialists on science policy in the USSR.[19] The Institute of Cybernetics has close ties with other R&D organizations and computer enterprises in the Ukraine, and "is one of the main institutes concerned with the computerization of the Soviet firm. Between 1961 and 1965 the institute worked on 43 contracts with industrial enterprises. Approximately 20-30 percent of its budget comes from contracts with industry."[20] One disadvantage of this close relationship with industry has been that "the requirements of industry often distract the institute from the theoretical side of its activities."[21]

The Institute of Cybernetics is also the largest research institute in the Academy of Sciences, with about 3000 employees as of 1971. Eventually the number is expected to total about 8000.[22] About 1500 are graduate students.[23] The average age of the Institute's employees

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[18] Ronald Amann, M. J. Berry, and R. W. Davies, "Science and Industry in the USSR," in Eugene Zaleski et al., *Science Policy in the USSR* (Paris, France: Organization for Economic Cooperation and Development, 1969), p. 447.

[19] Ibid., pp. 452-454.

[20] Ibid., p. 453.

[21] Ibid., p. 454.

[22] Barry W. Boehm, "Extensive Tour Yields Report on Current Soviet Computing," *Soviet Cybernetics Review*, Vol. 1, No. 1, February 1971, p. 11.

[23] Wade B. Holland, "Commentary," to V. M. Glushkov, "Trends in Soviet Computer Applications," translated in *Soviet Cybernetics Review*, Vol. 4, No. 4, April 1970, p. 20.

is very young. In 1968, it was reported that V. M. Glushkov was then 43, and that the average age of scientists and workers at the Institute was 29.[24]

The structure of this huge organization cannot be easily defined. In 1971, it consisted of five major departments: Engineering Cybernetics; Economic Cybernetics; Biological Cybernetics; Theoretical Cybernetics; and System Science.[25] Since 1967, some other subdivisions, reflecting the wide scope of the Institute, have been mentioned in the Soviet press, including the Control Computers Section; the Department of Analog Computers; the Section on Programming Automation; the Digital Automatons Section; and the Section on Complex Problems of Science. Like some large research organizations in other fields (but not necessarily typical of Soviet computer research organizations), it has its own Special Design Bureau as well as its own Computer Center. Two laboratories have also been mentioned: the Laboratory of Reading Automata and the Laboratory of Neurobionics. The Institute also presently houses the Ukrainian Republic Fund of Algorithms and Programs.

The Institute of Cybernetics is growing and changing rapidly. A number of smaller research organizations have broken off from it, and present plans call for reuniting these offshoots, together with the Institute of Cybernetics, into a new Cybernetics Center to be located in a suburb of Kiev. V. M. Glushkov is to be the head of this new organization. Reorganization plans have been underway for several years, but apparently the funding has not kept up with the plans. When the Supreme Soviet met in November 1971 to discuss the 1971-1975 Five-Year Plan, Glushkov urged that Gosplan supply special financing for completing the construction of the Cybernetics Center as quickly as possible.[26]

As indicated by its size and structure, the work of the Institute

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[24] "Sila vdoine" ["Twice as Strong"], editorial in *Nedelya*, January 28, 1968, p. 3.

[25] Boehm, op. cit., p. 9.

[26] V. M. Glushkov, "Text of Glushkov Address to Supreme Soviet," *Soviet Cybernetics Review*, Vol. 2, No. 5, September 1972, p. 20.

of Cybernetics has been far-ranging. Its products have encompassed hardware, including computers and auxiliary devices; software, hardware, and software systems, including multimachine systems; publications; conferences; dissertations; and other projects that defy classification.

The computers developed by the Institute of Cybernetics have been mainly small, special-purpose computers. These include: the Mir computer for engineering calculations (1964); the small integrating computer MIM designed by the Kiev computer (1964); the Dnepr-2 for use in automated management systems (1965-1966); the miniature computer "Syntax-1," which automatically pinpoints syntactic errors in programming languages (1966-1967); the Kiev-67, a special-purpose digital control computer (1967); the Ritm analog computer for solving PERT-type network scheduling (1967); the Promin'-M computer, a slightly modified version of the Promin' developed in 1962 by the Computer Center (1967); the Promin'-2 midget digital computer (1968?); the Arkus hybrid computer for solving sets of linear and nonlinear differential equations (1968); the ASOR-2 special purpose analog-digital computer used in network diagramming (1968); the Iskra desk model keyboard computer (1968); the Ros' table-model keyboard computer (1969); and the Mir-2 computer with a CRT terminal and light pen (1969).

Auxiliary devices developed by the Institute of Cybernetics include the following: an improved papertape input unit for Dnepr (1967); the ChARS-65 reading automaton (1967); the OKA reading automaton (1967); an input/output device for a Minsk-22 internal memory utilizing 15 telegraph channels (1969); an on-line graphic input terminal and light pen for the Mir-2 (1969); the Bloc-1 V device for handling data storage overflows (1970); a verbal recognition device (1971); in conjunction with workers at the Lvov TV plant, input/output devices for use with telephones, transmitters, and a display panel for the Lvov System (1969); and an artificial speaking device that enables the computer to report via a loudspeaker (1972).

The Institute of Cybernetics has experimented with multimachine systems. For example, they have been working on linking the Dnepr-2

with the BESM-6[27] and on interfacing the Mir-2 with the BESM-6.[28] They have also worked on hybrid (analog and digital) computer systems.

Work on elements of computers resulted in the development of a thin-film memory unit in 1967.[29] Joint work, conducted in 1968 with other research institutes, resulted in new, small, high-speed logic elements for digital computing devices, micromodules based on metal oxide semiconductors, and a series of cathode-ray tubes for outputting data from a computer.[30]

Most of the hardware developed by the Institute of Cybernetics has been produced by the Kiev Electronic Computer and Control Machines (VUM) Plant under the control of Minpribor. The Dnepr-2 computer, the Mir-1 computer, and the Mir-2 computer have all been produced at the VUM Plant, which participated in their development.[31] Some of the hardware developed by the Institute of Cybernetics has been farmed out to other plants. The Ritm computer, for example, is manufactured in Leningrad.[32] The Ros' keyboard computer developed by the Institute was consigned to the Tochelektropribor Plant in Kiev for serial production.[33] The Iskra desk model keyboard computer was developed by the Special Design Bureau of the Institute of Cybernetics in cooperation with the "Schetmash" Plant in Kursk, which then serially produced it.[34]

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[27] "Mir-2 and BESM-6 System?" *Soviet Cybernetics Review*, Vol. 2, No. 2, March 1972, p. 6.

[28] Boehm, op. cit., p. 10.

[29] Ya. V. Pejve, "Achievements in the Technical and Mathematical Sciences: 1968," *Soviet Cybernetics Review*, Vol. 4, No. 1, January 1970, p. 56.

[30] "Thin-film Memory Unit," *Soviet Cybernetics: Recent News Items*, No. 9, October 1967, p. 5.

[31] N. Dolotin, "Electronnyi inzhener" ["An Electronic Engineer"], *Ekonomicheskaya gazeta*, No. 9, 1970, p. 15; excerpts translated under the title "The VUM Plant," *Soviet Cybernetics Review*, Vol. 4, No. 5, May 1970, pp. 17-20.

[32] "Ritm Network Planning Computer," *Soviet Cybernetics Review*, Vol. 1, No. 1, February 1971, p. 38.

[33] "Press Review," *Soviet Cybernetics Review*, Vol. 4, No. 3, March 1970, p. 46.

[34] Photograph caption in *Pravda*, August 20, 1968, p. 3.

An especially interesting example of the Institute's "farming out" is that of the Promin'-M, which was serially produced by the Severodonetsk Instrument Construction Plant in the Ukraine. The Severodonetsk Plant in turn "produces most of the machines designed by the Severodonetsk Scientific Research Institute of Control Computers. Many of the computers developed at the latter Institute have incorporated hardware elements and operational features very similar to those of the Kiev and Dnepr line of computers."[35] The hardware of the M-1000, M-2000, and M-3000 computers, also developed by the Severodonetsk Institute, is based on the logic elements of the Mir-1, and it is difficult to say which came first.[36]

Software developed by the Institute of Cybernetics includes languages as well as programs. An address language for use in training future programmers in ALGOL-60; a digital modeling language called TSIMOD; languages for the Promin' and Mir computers; and the ANALITIK language for processing nonnumerical information (specifically mathematical formulas) using analytical methods in a man-machine dialogue mode[37] were all developed at the Institute. It is interesting to note that although the BESM-6 computer was developed by the Institute of Precise Mechanics and Computer Engineering in Moscow, COBOL and FORTRAN for the BESM-6 were worked out by the Institute of Cybernetics in Kiev.[38]

The Institute of Cybernetics has been heavily involved in the development of various computer systems. The most widely publicized automated management system is that of the Lvov Television Plant, developed jointly by the Institute and specialists at the plant. The Institute has been trying to generalize this system, based on the Minsk-22 computer, for use in other plants mass-producing a limited

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[35] Rudins, op. cit., p. 29.

[36] Wade B. Holland, "Soviet Computing, 1969: A Leap into the Third Generation?" *Soviet Cybernetics Review*, Vol. 3, No. 7, July 1969, p. 15.

[37] V. M. Glushkov et al., "Glushkov's New Language: ANALITIK," *Soviet Cybernetics Review*, Vol. 2, No. 2, March 1972, pp. 31-33.

[38] Holland, "The BESM-6 Computer," op. cit., p. 14.

number of products.[39] A Management Information System was developed by the Institute of Cybernetics for its own internal use.[40] According to a report in 1970, the Institute undertook "the basic part of the work in mathematical modeling and management system adaptation for the 16 largest industries of the Soviet Union."[41] No doubt some of these systems will be based on the Dnepr-2 complex, developed jointly by the Institute of Cybernetics and the Kiev Electronic Computer and Control Mechanics (VUM) Plant.[42] The "Bank" automated management system has also been developed by the Institute of Cybernetics for the Ukrainian SSR Stroibank (Bank for the Financing of Capital Investments).[43]

The development of such local automated management systems by the Institute of Cybernetics brings to mind the opinions of its director on implementing automated systems. Glushkov is the primary spokesman for the "bottom-up" approach to automation, that is, the practice of beginning with local systems that can later be linked into hierarchical networks, rather than working from the "top down" (from ministry to the plant). There is a long-standing controversy in the Soviet Union regarding this approach, and it has not as yet been resolved.[44]

Glushkov and his staff also seem to have a strong interest in automated design systems, especially for computers. In 1964, the Kiev computer was used to design the small integrating computer MIM.[45] By 1968, the Institute of Cybernetics had developed the Small Design

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[39] "The Lvov Production Control System," *Soviet Cybernetics Review*, Vol. 3, No. 3, March 1969, pp. 51-52.

[40] "Management Information System," *Soviet Cybernetics: Recent News Items*, No. 6, July 1967, p. 23.

[41] V. M. Glushkov, "Trends in Soviet Computer Applications," translated in *Soviet Cybernetics Review*, Vol. 4, No. 4, April 1970, p. 16.

[42] "High Precision Instruments," *Soviet Cybernetics: Recent News Items*, No. 13, January 1968, p. 19.

[43] Viktoriya Galuzinskaya, "Adaptive System for Bank," *Soviet Cybernetics Review*, Vol. 2, No. 2, March 1972, p. 50.

[44] Wade B. Holland, "Commentary" to S. Gurenko and N. Lisovenko, "Network Systems Require 'Top-Down' Approach," translated in *Soviet Cybernetics Review*, Vol. 4, No. 7, November 1970, p. 28.

[45] V. M. Glushkov, "Sopernik Konstruktora" ["The Designer's Rival"], *Nedelya*, No. 20, July 21, 1968, p. 6; translated in *Soviet Cybernetics: Recent News Items*, No. 21, September 1968, p. 19.

System to automate the design of small elements of a computer.[46] The Institute had also begun to develop a Large Automated Design System, of which the Small System would be one stage. In 1970, a state commission evaluated the PROEKT system based on an M-220 computer. The PROEKT system designs wiring diagrams for new computers, and can design computers containing as many as 5000 elements. It was claimed that "the research conducted has made it possible to automate 75 percent of computer design."[47]

Scientific Research Institute of Mathematical Machines of the Academy of Sciences of the Armenian SSR (Erevan)

The Scientific Research Institute of Mathematical Machines was founded in 1956 to fill the need for an Armenian Republic computer research institute. It was the result of "the efforts of a small group of electronics specialists (led by S. N. Mergelyan) of the Computer Laboratory of the Institute of Mathematics and Mechanics of the Armenian SSR Academy of Sciences."[48] Mergelyan was appointed its director and remains in that post today. He is also a Vice President of the Academy of Sciences of the Armenian SSR.

The series of computers for which the Scientific Research Institute is best known are the Nairis and the Razdans, all small digital computers. The Razdan computers are intended for the solution of scientific and engineering problems. The Razdan-1 was completed in 1960 but was never serially produced; it served as the prototype for the Razdan-2, the Soviet Union's first totally transistorized computer. Serial production of the Razdan-2 began in 1962 at the Erevan Elektron Plant. The Razdan-3, announced in 1965, is completely different from the earlier machines. It is much larger and more sophisticated in

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[46] V. M. Glushkov, "Na sluzhbe tekhicheskogo progressa" ["In the Service of Technical Progress"], in *Tekhnika i vooruzhenie* [*Technology and Armaments*], No. 9, 1968, pp. 24-26; excerpts translated under the title "Major Trends in Cybernetics," in *Soviet Cybernetics: Recent News Items*, Vol. 3, No. 2, February 1969, p. 44.

[47] S. Tsikova, "Mashina proektirvet mashinu" ["Machine Designs a Machine"], *Izvestiia*, April 19, 1970, p. 3; translated and paraphrased under the title "Kiev Automatic Computer Design System," in *Soviet Cybernetics Review*, Vol. 4, No. 7, July 1970, p. 39.

[48] Rudins, op. cit., p. 32.

terms of its hardware. A successor to the Razdan-3 was planned but has not been announced.[49]

The second highly successful series of the Erevan Scientific Research Institute is the Nairi series. It is claimed that more than 1500 Nairis are being used in the Soviet economy at the present time.[50] In 1971, the developers and manufacturers of the Nairi series were awarded a State Prize for their work on computers to be used in production and scientific research activities. The fully transistorized Nairi-1 was developed in 1964 and serially manufactured by the Erevan Elektron Plant beginning in 1965. Over 500 units of the Nairi-1 were produced (more than any other Soviet machine at the time) probably because "It was simple to construct and was quite reliable (by Soviet standards)."[51] The Nairi-2, developed in 1966-1967, had printed circuits. The Nairi-3, the first Soviet computer with integrated circuits, was completed in 1968-1969. It has also been manufactured by the Elektron Plant, but some production has now been transferred to the Baku Radio Factory in Aizerbaijan to make room for the new ES-1030,[52] an instance of higher-level decisionmaking.

The Erevan Scientific Research Institute of Mathematical Machines may have gained in importance (at least in the eyes of the Soviet government) with its participation in the development of the new third-generation ES (Ryad) series. A prototype of the ES-1030 was developed for test purposes at the Scientific Research Institute. According to a Soviet specification brochure, "The ES-1030 computer is a medium-productivity model in the Unified System of computers, and is intended for solving a wide range of scientific-technical, planning/economic,

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[49] Ibid., p. 33.

[50] K. Melikyan and A. Tatevosyan, "Elektronno-tsifrovaya vychislitel'naya mashina 'NAIRI-3'" ["Nairi-3 Electronic Digital Computer"], in *Vneshnyaya torgovlya* [*Foreign Trade*], No. 9, September 1972, pp. 40-41; translated under the title "Nairi-3 Described for Foreign Customers," in *Soviet Cybernetics Review*, Vol. 3, No. 2, March 1973, p. 13.

[51] Rudins, op. cit., p. 34.

[52] "Nairi-3 in Production Checkout," *Soviet Cybernetics Review*, Vol. 3, No. 3, May 1973, p. 30.

and data processing problems."[53] In April 1972, it was announced that the ES-1030 had successfully passed tests conducted by a state commission. Since that time, a major task of the Scientific Research Institute has been to prepare the ES-1030 for production.[54]

A number of other small computers were developed by the Scientific Research Institute but were produced in small numbers and not widely distributed. These include the Armenian Republic's first computers, which were designed in 1959-1960: the Aragats, "a vacuum-tube machine similar in design to the M-20; the Ararat, a lower-capacity version of the Aragats; and the Erevan, a small, one-of-a-kind, vacuum-tube machine."[55] These process control machines were preempted by the VNIEEM and the Dneprs. Another small process control computer, the Masis, was designed and produced at the Scientific Research Institute in 1965-1966. The first production model of the Masis was scheduled for delivery in late 1966, but little has been heard about it since.[56]

Institute of Electronic Control Computers (Moscow)

Some of the earliest small and medium-sized general-purpose digital machines were developed at the Institute of Electronic Control Computers during the 1950s by I. S. Bruk. In late 1951, the M-1, a prototype of the M-2, was developed. The M-2 appeared in 1953. The M-3, designed in 1957, turned out to be a highly modified version of the M-2, intended for small-volume mathematical calculations.[57] The only piece of hardware associated with the Institute of Electronic Control Computers since that time is the VA-345MK alphabetic-computational (factoring) machine.[58]

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[53] "Technical Data on the Unified System Computers," *Soviet Cybernetics Review*, Vol. 3, No. 6, November-December 1973, p. 12.

[54] "Ryad-30 Announced," *Soviet Cybernetics Review*, Vol. 2, No. 4, July 1972, p. 5.

[55] Rudins, op. cit., pp. 32-33.

[56] Wade B. Holland, "Masis Computer," *Soviet Cybernetics: Recent News Items*, Vol. 3, No. 5, May 1969, p. 52.

[57] Rudins, op. cit., pp. 7-8.

[58] "It Pays to Advertise," *Soviet Cybernetics: Recent News Items*, No. 2, March 1967, p. 3.

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Most of the more recent work of the Institute seems to center on research rather than on the development of computers. In 1961-1962, the Institute developed automated methods for the programmed monitoring of digital computers.[59] Some research on designing computers was reported in 1967,[60] and game-playing programs, said to have been given "considerable attention" at the Institute, were noted in 1969.[61]

INSTITUTES UNDER THE MINISTRY OF THE RADIO INDUSTRY

The research and design organizations under the Ministry of Radio Industry mainly develop scientific machines but they also do some work on process control computers. They vary considerably in their location and proximity to production facilities of the ministry. The main computer hardware organizations under the Ministry of the Radio Industry include the Design Bureau and the Special Design Bureau of the Minsk Ordzhonikidze Computer Factory; the Design Bureau of the Penza Computer Plant; and the Scientific Research Institute of Calculating Machine Construction (NIISchetmash) in Moscow.

Design Bureaus of the Minsk Ordzhonikidze Computer Factory

Some of the most important computer research in the Soviet Union, and certainly the most significant research in Belorussia, is carried on at the Design Bureau of the Minsk Ordzhonikidze Computer Factory, headed by V. V. Przhiyalkovskii. It is here that the Minsk line of process control computers, one of the most widely used series of computers in the USSR, was developed. The first Minsk machine, the Minsk-1, was begun around 1956 and was completed in 1958-1959. It was put into serial production in 1960 and about 200 units were built. Immediately after the Minsk-1 had been completed, work began on the

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[59] "Computer Malfunction Diagnostics," *Soviet Cybernetics: Recent News Items*, No. 5, June 1967, p. 67.

[60] V. N. Lopato, "Ccnference on Design of Radioelectronic Equipment," *Soviet Cybernetics: Recent News Items*, No. 23, November 1968, p. 86.

[61] Melvin Dresher, "Soviet Research in Game Theory Applications," *Soviet Cybernetics: Recent News Items*, Vol. 3, No. 4, April 1969, p. 62.

Minsk-2 and was finished in 1961. The Minsk-2 was put into serial production in 1962 and about 300 units were produced. The Minsk-2 was followed by the Minsk-22, improved by better input-output equipment. A prototype of the Minsk-22 was built in 1963, and over 300 units were manufactured in serial production beginning in 1965.[62] The Minsk-11, Minsk-12, and Minsk-14 were developed between 1961 and 1964, "but little is known about them and few were built."[63]

Two versions of the Minsk-22 were developed in the middle sixties. The Minsk-22M was designed in 1965-1966 for engineering calculations. Another version of the Minsk-22 was designed for information processing in business and management. This version, known as the Minsk-23, was designed in 1964 and put into serial production in 1966.

The largest and fastest machine in the Minsk line is the Minsk-32. It is possible to connect as many as 136 input-output devices to this machine, which greatly increases the range of problems it can solve in various fields beyond the ones of process control and engineering handled by earlier Minsk machines.[64] The Minsk-32 was developed in 1968 and put into series production in 1969.[65]

A more recent major project of the Design Bureau has been the development of the ES-1020 in 1971, one of the first machines to appear in the joint Soviet-Eastern European Ryad effort. The machine was designed with the participation of Bulgarian specialists.[66] According to a Soviet specification brochure, "the ES-1020 computer is one of the smaller Unified System computers, and is intended for solving a wide range of scientific-technical and planning/economic problems, in addition to operating in automated control systems."[67]

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[62]Rudins, op. cit., p. 34.

[63]Ibid., p. 35.

[64]Ibid.

[65]"Ponravitsia vsem" ["Everybody Likes It"], *Pravda*, January 5, 1969, p. 6.

[66]M. Shimanskij and N. Novikov, "Problem-Plagued Ryad Machine Announced," *Soviet Cybernetics Review*, Vol. 2, No. 3, May 1972, p. 13.

[67]"Technical Data on the Unified System Computers," *Soviet Cybernetics Review*, Vol. 3, No. 6, November-December 1973, p. 15.

In January 1972, A. A. Reut, Director of the Minsk Factory, announced that the ES-1020 had passed all the tests conducted by a committee made up of Council of Mutual Economic Aid (CEMA) representatives. At that time, it was also announced that the Minsk Factory had produced and delivered the first units of the ES-1020 to customers. At the same time, the Minsk Factory was continuing to produce the Minsk-32 computer at a rate of 500 to 600 units per year.[68] In July 1972, it was announced that the ES-1020 was also being produced at the Brest Electromechanical Plant located, like the Minsk Factory, in Belorussia.[69]

The Special Design Bureau of the Minsk Ordzhonikidze Factory, headed by G. P. Lopato, has participated in the development of a general-purpose multimachine system called the Minsk-222 Computer System. The research work for the system was done at the Institute of Mathematics of the Siberian branch of the USSR Academy of Sciences in Novosibirsk, but the experimental model of the system was engineered by the Special Design Bureau in Minsk.[70] The Minsk-222 was tested both in Novosibirsk and at Minsk.[71] The system is based on Minsk-2 and Minsk-22 computers. A configuration using two Minsk-22 machines and one Minsk-2 was reported to be in the testing stage in 1968, but "there are indications that this multimachine-system project has been abandoned."[72]

Besides producing computer hardware and systems, the Minsk Ordzhonikidze Factory also trains computer specialists. An article published in 1972 said that the factory annually trains more than 2000 specialists, but that the training process is not organized

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[68] Wade B. Holland, "Unwrapping the ES Computers," *Soviet Cybernetics Review*, Vol. 3, No. 5, September 1973, p. 17.

[69] "ES-1020 in Production," *Soviet Cybernetics Review*, Vol. 2, No. 5, September 1972, p. 5.

[70] "Errata," *Soviet Cybernetics: Recent News Items*, No. 7, August 1967, p. 2.

[71] Wade B. Holland, "Soviet Cybernetics Highlights, 1966," *Soviet Cybernetics: Recent News Items*, No. 7, August 1967, p. 12.

[72] Rudins, op. cit., p. 37.

satisfactorily due to inadequate quarters. Plans for the construction of a new educational complex at the factory have been developed.[73]

Design Bureau of the Penza Computer Plant

One of the earliest Soviet machines to be produced industrially on a large scale was the Ural-1. It was designed by Yu. Ya. Basilevskij of the Institute of Mechanics and Instrument Design of the Ministry of the Radio Industry, and produced at the Penza SAM Plant beginning in 1955. Work on the Ural line of computers was later taken over by the product engineering group at Penza. The group was led by B. I. Rameev, who had worked with Basilevskij on the design of the Ural-1.

The product engineering group designed the Ural-2 in 1958 and the Ural-4 in 1960. During the 1960s, the group devoted its efforts to developing the first Soviet series of compatible computers, intended for data-processing applications. The Ural-11 and Ural-14 computers were completed in 1963, and they were put into serial production in 1964. A prototype of the third machine in the series, the Ural-16, was completed in 1965. The Ural-16 was scheduled for production in 1967, but little has been heard of it since.[74]

Since the ES-1050, a large machine in the third-generation Ryad line, is being manufactured at Penza,[75] it may be assumed that the design group participated in its development. It is the only computer in the ES series known to have been both developed and produced exclusively by the USSR. (The ES-1060 is scheduled for exclusive production, but there have been problems with its development.) According to a Soviet specification brochure, the ES-1050 "is a high-productivity machine intended for solving a wide range of scientific-technical, economics, and specialized problems."[76]

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[73] I. Novikov, "Pust' mashiny dumayut luchshe" ["Let the Machines Think Better"], *Pravda*, July 27, 1971, p. 2; translated under the title "Central Servicing for Minsk Computers Tried," *Soviet Cybernetics Review*, Vol. 1, No. 6, November 1971, p. 18.

[74] Rudins, op. cit., p. 21.

[75] Holland, "Unwrapping the ES Computers," op. cit., p. 17.

[76] "Technical Data on the Unified System Computers," op. cit., p. 7.

Scientific Research Institute of Calculating Machine Construction (NIISchetmash) (Moscow)

In 1960, the Scientific Research Institute of Calculating Machine Construction of the USSR State Committee on Radioelectronics (the organizational predecessor of the USSR Ministry of the Radio Industry until 1965)[77] designed the Era computer. The Era was a vacuum-tube machine intended for data processing. Although it was a temporary improvement over the Lems and the Urals then available, it was quickly superseded by the more advanced transistorized Ural models.[78]

Also in the early sixties, the Scientific Research Institute designed the ATE-80 punchcard calculator (1961-1962). However, an experimental model of the ATE-80 was not tested until around 1965. It was then put into serial production at a plant in Vilnius, Lithuania (around 1966).[79]

Another piece of hardware designed by NIISchetmash is the Doza analog computer, developed in 1969. The Doza is used to calculate doses of radiotherapy in treatment of malignant tumors. This work was commissioned by the State Scientific Research Institute of Roentgenology and Radiology.[80]

Besides individual computers, NIISchetmash has also produced at least one computer-based system, the NPI (scientific information transmission) system. The NPI system was intended to solve, automatically, "problems related to dispatching, operational control, and monitoring of production on the basis of data received from different processing points."[81]

In addition to being a computer hardware research institute, NIISchetmash has apparently also functioned as a production facility

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[77] See p. 35 for further details.

[78] Rudins, op. cit., p. 9.

[79] Ibid., p. 6.

[80] V. A. Golovan et al., "The Doza Analog Computer," *Soviet Cybernetics Review*, Vol. 3, No. 9, September 1969, p. 111.

[81] "Sistema NPI" ["The NPI System"], *Ekonomicheskaya gazeta*, No. 43, October 1967, p. 45.

(see Section V). Another of its functions is to provide software. NIISchetmash and the Minsk Ordzhonikidze Factory were supposed to supply programs for the Minsk-32 developed by the Factory, but the Institute did not have enough programmers to meet this demand. G. D. Smirnov, the Institute's Chief Engineer, commented that if the Institute were staffed with experts from all branches of the national economy, science, and urban affairs, the staff "would grow beyond reasonable bounds and would be impossible to manage."[82]

INSTITUTES UNDER THE MINISTRY OF INSTRUMENT CONSTRUCTION, MEANS OF AUTOMATION, AND CONTROL SYSTEMS (MINPRIBOR)

The research institutes and design bureaus under the Ministry of Instrument Construction, Means of Automation, and Control Systems (Minpribor) specialize in process control and industrial computers rather than in scientific or engineering machines. As in the case of the Ministry of the Radio Industry, the research and design organizations of Minpribor are widely dispersed in a geographic sense. The main computer hardware institutes under Minpribor include the Severodonetsk Scientific Research Institute of Control Computers; the Tbilisi Scientific Research Institute of Instrument Construction and Means of Automation; and the design bureaus of the Sigma Association of Calculating and Organizational Equipment Enterprises (Vilnius).

Severodonetsk Scientific Research Institute of Control Computers (NIIUVM)

The Severodonetsk Institute is more specialized in the scope of its work than many of the other research organizations. It produces only control computers and systems based on those computers. A group of three early computers were developed into the SOU-1 control system in 1965 and displayed at the Interorgtekhnika Exhibit in Moscow in 1966. Design of one of the machines, the MPPI-1, was

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[82] N. Novikov, "Letters Uncover Problems in Minsk," *Soviet Cybernetics Review*, Vol. 2, No. 6, November 1972, p. 34.

completed around 1962-1963. "It can function independently or as a part of the SOU-1 system."[83] A second machine in the SOU-1 system, the UM-1 control computer, was developed around the same time, and is produced by the Severodonetsk Computer Factory. The KVM-1 general-purpose computer was designed to be the executive machine in the SOU-1 system. "The date work began on this computer is not known, but it was put into serial production in 1965."[84]

However, a report in 1970 indicated that there was no evidence that the SOU-1 system was actually being used. One possible reason was that the machines in the system were not compatible (for instance, in word length), and they may never have functioned efficiently as a system. Another explanation may be that the work on the SOU-1 system was subsumed into work on the ASVT-D[85] project assigned to the Severodonetsk Scientific Research Institute of Control Computers in 1965 by Minpribor. The fact that the M-3000, the largest of the machines in the ASVT-D series, "is remarkably similar in performance to the KVM-1"[86] supports this explanation.

Work on the ASVT (modular computer systems) and Ryad projects signalled a major effort on the part of the Soviets to develop modular third-generation computers compatible with the IBM System/360. It should be noted that this effort was made within the framework of the Soviet computer industry as it existed at that time, under the Ministry of Instrument Construction, and without apparently changing the existing organizational arrangements. A later effort to develop modular third-generation machines compatible with the IBM System/360 (the ES or Ryad machines) was made by giving overall responsibility to a new intergovernmental commission, which seems to be directing the activities of the Soviet Ministry nominally in charge of the development (Ministry of the Radio Industry). Overall, the trend in the Soviet computer industry seems to be toward greater centralization of control.

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[83] Rudins, op. cit., p. 29.

[84] Ibid.

[85] Modular System of Computer Hardware based on discrete elements.

[86] Rudins, op. cit., p. 31.

This trend is discussed in Section II, "Party-Government Intervention in the Soviet Computer Industry."

An unusual feature of the ASVT machines has been pointed out by Wade Holland:

> The M-1000, M-2000, and M-3000 are based on logic elements designed for the Mir-1. This could indicate a design collaboration between Glushkov's Institute of Cybernetics [under the Ukrainian Academy of Sciences] and the Severodonetsk Institute, both of which are located in the Ukraine. It is also possible that the M machine models were built at the same Kiev factory that makes the Mir computers, thus accounting for the use of the same logic elements. A more intriguing, if less substantive, speculation is that these elements were originally designed for the ASVT machines, and their use in the Mir came later. This interpretation appeals to those who feel that the Mir does not represent advances in the technology commensurate with the adulation and honors which have been bestowed on Glushkov and his Institute for its design.[87]

Whatever the explanation, the situation is considered unusual: "Soviet research institutes are usually very competitive (much like U.S. industrial laboratories) and do not share their discoveries with other organizations unless ordered to do so by the State.[88]

Serial production of the M-1000, M-2000, and M-3000 machines in the ASVT series was announced in 1969. However, while it had appeared earlier that all of this work was based in Severodonetsk, it turned out that the design of the M-1000--unlike the M-2000 and the M-3000--was completed by the Tbilisi Scientific Research Institute of Instrument Construction and Means of Automation.[89] This seemed to explain some inconsistencies in the ASVT series; for example, the instruction repertoire for the M-1000 machine is different from that of the M-2000 and the M-3000.

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[87] Holland, "Soviet Computing, 1969: A Leap into the Third Generation?" op. cit., p. 15.

[88] Rudins, op. cit., p. 31.

[89] Wade B. Holland, "Commentary" to G. Lebanidze, "Serial Production of M-1000 Approved," translated in *Soviet Cybernetics Review*, Vol. 4, No. 3, March 1970, p. 3.

The Severodonetsk Scientific Research Institute of Control Computers has been involved in the development of several systems based on computers that it has designed, such as, for example, the "Avtodispetcher," an information control system based on the UM-1 computer.[90] A control system for petroleum processing plants based on the M-3000 control computer was also developed by the Severodonetsk Institute. The Severodonetsk Chemical Combine was aided in the process of mechanizing and automating production by the Scientific Research Institute of Control Computers, among others. Perhaps the best-known system in which the Severodonetsk Institute has participated is the Sirena automated system for seat reservations and ticket sales used by Aeroflot in Moscow.[91]

<u>Tbilisi Scientific Research Institute of Instrument Construction and Means of Automation</u>

Although, until recently, the Tbilisi Scientific Research Institute of Instrument Construction and Means of Automation was notable for only minor achievements in the computer industry, it is emerging as a new center for the development of special-purpose machines. This new role has been perceived as a result of the announcement that the M-1000 (of the ASVT-D series) was developed at the Tbilisi Institute with the help of scientists and workers of other enterprises under Minpribor.[92] The model of the M-1000 was submitted to the appropriate state commission by the Tbilisi Institute in 1969. In the same year, "serial production of the M-1000 was begun by the Tbilisi Experimental Plant of Control Computers and the Experimental Plant of the Tbilisi Scientific Research Institute of Instrument Construction and Means of

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[90] Yu. D. Shcherbashin, B. I. Bakaj, V. V. Przhegarlinskij, "The Automated Control System of the Ammonium and Alcohol Plant," *Soviet Cybernetics: Recent News Items*, No. 22, October 1968, pp. 69-72.

[91] Yu. F. Bubennov and I V. Makaranets, "Technical Description of the Sirena System," *Soviet Cybernetics Review: Recent News Items*, Vol. 3, No. 3, March 1969, p. 31.

[92] G. Lebanidze, "Serial Production of M-1000 Approved," *Soviet Cybernetics Review*, Vol. 4, No. 3, March 1970, p. 3.

Automation."[93] The M-1000 will be used in the chemical, metallurgical, power, and food industries, in the production of construction materials, and in a number of other branches of the national economy. Like the M-2000 and the M-3000, the M-1000 logic system is based on that of the Mir-1, which was designed by the Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR in Kiev.[94]

An earlier computer developed by the Tbilisi Institute is the Tbilisi-1, which was first noted in October 1967. It is a special-purpose machine, originally designed for process control in the cement industry, which can also be used for automated control and for monitoring other continuous technological processes. The basis of the logic system of the Tbilisi-1 is the Ural-10 modular system of potential elements. The original model of the Tbilisi-1 was built in the Experimental Plant of the Tbilisi Institute, and it has been approved for serial production by a state commission.[95]

A number of other special-purpose computers for use in the metallurgical industry have been developed by the Tbilisi Institute on the basis of the research done for the ASVT modular computer. One of these is a special-purpose computer for automated mixing in an agglomeration factory. A second is the Amplituda special-purpose computer for measuring the area of tin plate, and a third is the Dispersiometr special-purpose computer for automating the identification of compounds.[96]

The Tbilisi Scientific Research Institute of Instrument Construction and Means of Automation also has developed two keyboard computers that are in production at the Tbilisi Control Computers Plant. The

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[93] G. A. Gegeshidze, "New from Georgia: Tbilisi-1, M-1000, Special Computers," *Soviet Cybernetics Review*, Vol. 4, No. 8, September 1970, p. 32.

[94] V. M. Kostelyanskij and V. A. Barabanov, "ASVT Modular Computer System," translated under the title "M-Series of ASVT Computers Described," in *Soviet Cybernetics Review*, Vol. 4, No. 9, November 1970, p. 37. The Iskra-11, Iskra-12, and Iskra-22 are also said to be based on the Mir-1 logical elements. See pp. 107 and 108 of this report.

[95] "Tbilisi-1 Control Computer," *Soviet Cybernetics: Recent News Items*, No. 24, December 1968, p. 5.

[96] Gegeshidze, op. cit., pp. 32-33.

Gelati-3 computer, developed in 1968, was designed for engineering, statistical, and accounting calculations. The Gelati-5 keyboard computer, developed in 1970, is intended for accounting, economic, and statistical calculations.[97]

Design Bureaus of the Sigma Association (Lithuania)

There are three design bureaus in the Sigma Association of Calculating and Organizational Equipment Enterprises: the Special Computer Design Bureau; the Special Design Bureau for Organizational Technology; and the Special Planning and Design Bureau for Management Systems. The Sigma Association is a Main Administration of Minpribor and, unlike other Main Administrations under Minpribor, it is a territorial division, with all of its enterprises located in Lithuania. It was the first Main Administration to operate on a cost-accounting basis (as of July 1, 1966).[98]

The directors of the three design organizations serve on the council of directors of the Sigma Association, along with their counterparts from the seven enterprises in the Association, the Association chief, and two of his deputies. However, V. Koval', Chief Engineer of the Sigma Association, has pointed out certain problems of technical services[99] and design. "To improve coordination of the activities of the technical sub-divisions of the association and to raise the level of engineering policies," an engineering council of the Main Administration was formed.[100] The engineering council includes the chief specialists of the enterprises and designing

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[97] "Gelati Computers," *Soviet Cybernetics Review*, Vol. 2, No. 3, May 1972, p. 48.

[98] "Cost Accounting Successful in Sigma Association of Calculating and Organizational Equipment Enterprises," *USSR Industrial Development, Electronics and Precision Equipment*, No. 26, *JPRS:* 41,670. (Joint Publications Research Service, TT:67-32302), July 1, 1967, pp. 1-2.

[99] The original Russian word used is translated as "services"; "staff" might be a better equivalent in English, however.

[100] "Cost Accounting Successful in Sigma Association of Calculating and Organizational Equipment Enterprises," op. cit., p. 7. For a detailed discussion of the technical services of the Sigma Association, see Section V, p. 111.

organizations, as well as representatives of the Kaunas Polytechnical Institute and of a number of institutes of the Academy of Sciences of the Lithuanian SSR.

The major achievement of the Special Design Bureaus of the Sigma Association has been the development of the M-5000 process control computer. This machine is part of the ASVT-M line of computers, or Modular System of Computer Hardware based on microelectronics. It is much smaller than its predecessors from the ASVT-D line of computers, or Modular System of Computer Hardware based on discrete elements. (The two lines have been developed at various research institutes under Minpribor.) The M-5000 is intended for complex economic calculations. Production of the machine began at the Vilnius Calculating Machines Plant in 1972.[101]

One of the most important achievements of the Sigma Association's Special Design Bureaus is the Ruta-110 information-processing system, developed in 1964-1965. It was designed for data-processing and low-level management information applications. By 1966, the Ruta had been put into serial production.[102] The time required to develop the Ruta was greatly decreased by constructing a model of the complex in parallel with the design.[103] Although not considered to be a sophisticated electronic computer by the Soviets themselves, the Ruta-110 was said to be "the first computer to be well provided with peripheral equipment."[104] A number of configurations of the Ruta complex were developed. The Ruta-110D was supposed to be equipped with magnetic disc storage; the Ruta-110I is the information-processing model; and the Ruta-110K is the card model (so-called because it uses punchcards and papertape for storage).[105]

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[101] "Zatrat men'she, produktsii bol'she" ["The Less the Losses, the More the Production"], *Izvestiia*, August 16, 1972, p. 1.

[102] Rudins, op. cit., p. 37.

[103] "Efekt Sliyaniya" ["Merging Effect"], *Ekonomicheskaya gazeta*, No. 3, January 1968, p. 8.

[104] Uri Kamin, "The Ruta-110 Computer Complex, *Soviet Cybernetics Review*, Vol. 3, No. 9, September 1969, p. 37.

[105] Rudins, op. cit., p. 38.

Another product of the Association's Special Design Bureaus is the Ruta-701 reader, said to be the first industrial reading device in the Soviet Union.[106] It can read typed or standardized handwritten data, which it then codes and feeds into a computer on papertape.[107]

The main responsibility of the Special Planning and Design Bureau for Management Systems is "the planning and introduction of branch and departmental automated control systems based on computer hardware produced by the main administration."[108] They also develop and introduce new technology and hardware for mechanizing and automating labor processes and help to organize production at Association enterprises. The close collaboration of all the suborganizations within the Sigma Association makes it possible for the Special Planning and Design Bureau to prepare for the production and implementation of new computer systems while they are still in the planning stage. This was possible when the Ruta-110 complex was introduced into the control system of the Vilnius Calculating Machines Plant.

OTHER INSTITUTES

There are two institutes under the control of organizations other than the Academy of Sciences system, the Ministry of the Radio Industry, or Minpribor: the Laboratory of Electromodeling (LEM) of the All-Union Institute of Scientific and Technical Information (VINITI) and the Elektronika Institute in Kiev.

Laboratory of Electromodeling (LEM) of the All-Union Institute of Scientific and Technical Information (VINITI)

The Laboratory of Electromodeling (LEM) of the All-Union Institute of Scientific and Technical Information (VINITI) has conducted some research on computer hardware. VINITI is under the joint control

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[106] "A Computer Reads a Manuscript," *Soviet Cybernetics: Recent News Items*, No. 18, June 1968, p. 37.

[107] "Ruta-701 Reads Handwritten Text," *Soviet Cybernetics: Recent News Items*, Vol. 3, No. 5, May 1969, p. 1.

[108] V. Paura, "Kollektivnyi glavnyi tekhnology" ["Collective Chief Technologist"], *Ekonomicheskaya gazeta*, No. 23, June 1967, pp. 10-11.

of the USSR State Committee on Science and Technology and the USSR Academy of Sciences. In cases of joint control by the Academy of Sciences and a government organ, it may be assumed that funding is provided and controlled by the government organ, and that the Academy of Sciences serves in a guiding rather than controlling capacity.

The Laboratory of Electromodeling, headed by L. I. Gutenmakher, did some early work on information-retrieval machines, but without much success. The only product of this work seems to have been the Lem, a small general-purpose digital computer. The Lem-1 was developed in 1955, with an improved model, the Lem-1-16, following in 1957. A further improved model, the Lem-1-24, appeared later. All of these machines were designed for solving mathematical problems and for experimental work in solving logical and data-processing problems. The Lems could not compete with the Ural machines, however, and they did not stay on the Soviet computer market for long.[109]

Another major hardware project undertaken by the Laboratory of Electromodeling was the development of a reading automaton using a Ural-4 computer. The reader was approved by a state commission in 1964, and was then used in the Laboratory for research purposes.[110] In 1967, the reading automaton was improved by a high-speed scanner-transport device developed jointly by the Laboratory of Electromodeling and the Odessa Electrical Engineering Institute of Communications.[111]

Elektronika Institute (Kiev)

The Elektronika Institute is located in Kiev, but its organizational subordination is not known. It developed the Elektronika K-200 control computer, which was put into production at the Pskov Radio Parts Plant in 1971. The K-200 can be used to manage technological production processes in industry or to control the operation

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[109] Rudins, op. cit., p. 9.

[110] M. L. Avrukh, "Automatic Text Reading," *Soviet Cybernetics: Recent News Items*, No. 3, April 1967, p. 22.

[111] Stephan, op. cit., p. 14.

of an atomic reactor.[112] Because of the power requirements of the K-200, its size, and "the completeness and sophistication of its design and production availability package" (software is included), it has been speculated that this machine may have military or space origins.[113]

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[112]"Computer To Control Atomic Reactors," *Soviet Cybernetics Review*, Vol. 1, No. 6, November 1971, p. 5.

[113]Wade B. Holland and Willis H. Ware, "K-200: Space Computer or Engineering Oddity?" *Soviet Cybernetics Review*, Vol. 2, No. 3, May 1972, p. 19.

Fig. 2--Locations of Soviet computer organizations and production facilities

V. SOVIET COMPUTER PRODUCTION FACILITIES

About thirty Soviet computer production facilities have been identified by name. Some information is available from the open literature on about twenty-five of them, and the organizational subordination is known for at least twenty. Most of the facilities seem to be under the jurisdiction of one of two ministries: the Ministry of the Radio Industry or the Ministry of Instrument Construction, Means of Automation, and Control Systems (Minpribor). (In April 1966, responsibility for the design and production of all forms of computer technology was clearly divided between the Ministry of the Radio Industry and Minpribor by a resolution of the Central Committee of the CPSU and the Council of Ministers of the USSR, although in actual practice there seems to be some overlap.)

Whether some small production facilities still remain under one of the divisions of the USSR Academy of Sciences is not known for sure. At least one, the Minsk Ordzhonikidze Computer Factory, is believed by some American experts to have been under the jurisdiction of the Belorussian Academy of Sciences before it was taken over by the Ministry of the Radio Industry.

In the following discussion, the information on the various Soviet computer facilities is necessarily sketchy and draws heavily on the *Soviet Cybernetics Review*, because the time constraints of this study did not permit a survey of all the available Soviet literature. The main purpose of this section is to lay out the patterns and relationships of the Soviet computer production facilities, and to illustrate the role of individual computer facilities within the general scheme of the Soviet computer industry. Information on each facility includes, wherever possible, some indication of its age and importance, the important machines and equipment it produces, production dates and quantities where available, the quality of its products (if known), the relationship of the facility to research institutes (if any), and other activities of the facility thought to be of importance to the computer industry as a whole. The geographic

dispersion of the Soviet computer industry, pointed out in Section IV, is clearly evident in Fig. 2.

PLANTS UNDER THE MINISTRY OF THE RADIO INDUSTRY

At least six of the Soviet computer production facilities are believed to be under the jurisdiction of the Ministry of the Radio Industry at the present time. These include the Brest Electromechanical Plant, the Minsk Ordzhonikidze Computer Factory, the Moscow Calculating and Analytical Machines (SAM) Plant, the Penza Electronic Computer (SAM) Plant, the Elektron Computer Plant in Erevan, and the Baku Radio Factory in Azerbaijan.

Baku Radio Factory (Azerbaijan)

Very little is known about the Baku Radio Factory, except its location, which is in the Azerbaijan SSR. Presumably this facility is under the administration and control of the Ministry of the Radio Industry. Its name would seem to indicate such subordination, and one of its products, a Nairi machine, has been produced in the past by another facility under the Ministry of the Radio Industry.

The Nairi-3-1, designed by the Erevan Scientific Research Institute of Mathematical Machines of the Academy of Sciences of the Armenian SSR, was formerly produced by the Erevan Elektron Plant, under the control of the Ministry of the Radio Industry. Apparently some (if not all) of the Nairi-3-1 computer production was transferred to the Baku Radio Factory[1] to make room at the Erevan Elektron Plant for production of the ES-1030, a medium-sized Ryad machine.

Brest Electromechanical Plant

The Brest Electromechanical Plant, which seems to be fairly new, is the second factory in Belorussia to manufacture computers (the other is the Minsk Ordzhonikidze Computer Factory). In July 1972, production began on the smallest machine in the important

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[1]"Nairi-3 in Production Checkout," *Soviet Cybernetics Review*, Vol. 3, No. 3, May 1973, p. 30.

third-generation Ryad series, the ES-1020.[2] The following year, an assembly line was installed in the plant for the production of ES-1020 computer frames. This step was said to have increased productivity and quality in the manufacturing process.[3]

In addition, the Brest-11 papertape perforator has been developed and put into production. The Brest-11 is intended for specifying production processes and for duplication of prepared tapes, but it can also be used for program-controlled machines requiring papertape programs.[4]

Minsk Ordzhonikidze Computer Factory

The Minsk Ordzhonikidze Computer Factory in Belorussia is one of the oldest and most important of all Soviet computer facilities. The Minsk line of computers has been both designed and built at this factory.[5] The electronic computers manufactured at the Minsk Factory are the most widely distributed computers in the national economy of the Soviet Union. Series production of the latest in the Minsk line, the Minsk-32, began in 1969 and continued at least through 1973 at the rate of 500 to 600 units a year, even after the beginning of work on the ES computers.[6]

In 1968, the Minsk Ordzhonikidze Factory was identified as the headquarters for the third-generation Ryad project. In 1972 it was announced that the factory had produced and delivered to users the first units of the new ES-1020 computer, based on integrated circuits. A. A. Reut, Director of the factory, also stated that the computer had

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[2] "ES-1020 in Production," *Soviet Cybernetics Review*, Vol. 2, No. 5, September 1972, p. 2.

[3] "Brest-11 Perforator," *Soviet Cybernetics Review*, Vol. 3, No. 3, May 1973, p. 6.

[4] "EVM na konvejere" ["Computer on a Conveyer"], *Izvestiia*, August 22, 1973, p. 3.

[5] George Rudins, "Soviet Computers: A Historical Survey," *Soviet Cybernetics Review*, Vol. 4, No. 1, January 1970, p. 34.

[6] Wade B. Holland, "Unwrapping the ES Computers," *Soviet Cybernetics Review*, Vol. 3, No. 5, September 1973, p. 17.

passed extremely rigid acceptance tests conducted by a committee made up of CEMA representatives.[7]

In addition to these major projects, the Minsk Factory has developed and manufactured some peripheral equipment, including the first known magnetic disk storage device in the Soviet Union, patented but not yet in production as of 1967.[8] The development of the Soviet disk represents approximately a 10-year lag behind the United States in the development of comparable disk storage. Other peripheral equipment produced by the Minsk Factory includes a unit called "Blank" to input data written on a paper form;[9] the Minsk-1500 unit for transmission of data by telephone lines;[10] and a device for reading forms with graphic notations and special fonts.[11] The FSM-ZN papertape reader, being manufactured by the Minsk Factory in 1968, was considered to be "the best serially produced device of its kind in the USSR" at that time.[12]

The Minsk Factory has shown much more concern over the effective use of the computers it manufactures than is typical of other Soviet computer plants. In 1968, V. Gol'dberg, then the Director of the Minsk Factory, in an article in *Ekonomicheskaya gazeta* stated that "several years ago, specialists at our factory suggested that the introduction of electronic computers was the responsibility of those who produced them. In principle, this suggestion was not rejected,

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[7] M. Shimanskij and N. Novikov, "Problem-Plagued Ryad Machine Announced," *Soviet Cybernetics: Recent News Items*, Vol. 2, No. 2, May 1972, p. 13.

[8] "Soviet-Developed Disc Patented," *Soviet Cybernetics: Recent News Items*, No. 9, October 1967, p. 3.

[9] I. Novikov and A. Simurov, "Pamyat' na ladoni: O tekh, kto sozdaet schetno-elektronnye mashiny" ["Memory on a Palm: Developers of Computers"], *Pravda*, December 2, 1967, p. 6.

[10] Ibid.

[11] Ibid.

[12] "Five Soviet Papertape Readers," excerpted and translated in *Soviet Cybernetics: Recent News Items*, Vol. 3, No. 2, February 1969, p. 93.

but organizationally it was not supported."[13] Subsequently, the Minsk Factory did organize a special section to install and service computers, to train customers in their use, and to collect data on their operation. Gol'dberg maintained in this article that the manufacturer had the further responsibility of determining in which organizations computers should be introduced and in seeing to it that they were used efficiently once they were in operation.

Six months after the publication of the above article, K. D'yakov, an official from the "Avtomatika" All-Union Design and Installation Association under Minpribor, opposed Gol'dberg's view. D'yakov asserted that responsibility for the distribution, installation, servicing, and even the technical servicing should be left in the hands of "Avtomatika," which was set up to develop and service automated control systems (in 1966).[14] A point he failed to mention, however, is that the Minsk Factory functions under the control of the Ministry of the Radio Industry. The "Avtomatika" Association, on the other hand, "was based on the project and experimental design organizations and on the industrial and repair subdivisions of the USSR Ministry of Instrument Construction, Means of Automation, and Control Systems."[15] Since Minpribor is officially responsible for control and automation hardware (as opposed to general-purpose hardware, which is the province of the Ministry of the Radio Industry), it seems logical that the "Avtomatika" Association should function under Minpribor. In actual practice, Radio Ministry computers (such as the Minsk machines) are used for industrial purposes, and conflict results between the two ministries.

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[13] V. Gol'dberg, "Malo izgotovit' mashinu" ["It's Not Enough To Produce a Computer"], in *Ekonomicheskaya gazeta*, No. 2, January 1969, p. 17; translated under the title "Manufacturer's Responsibility for Introduction of Computers," *Soviet Cybernetics: Recent News Items*, Vol. 3, No. 1, January 1969, p. 6.

[14] K. D'yakov, "Razobshchennye usiliya" ["Disconnected Efforts"], *Sotsialisticheskaya industriya*, June 18, 1970, p. 2; translated under the title "The Manufacturer's Responsibility: An Opposing Viewpoint," in *Soviet Cybernetics Review*, Vol. 4, No. 8, September 1970, pp. 23-24.

[15] Ibid., p. 23.

Along with the Penza Plant (also under the Ministry of the Radio Industry), it was claimed, in 1969, that the Minsk Factory has been the only Soviet manufacturer to regularly ship computer systems to customers assembled and ready for installation.[16] (It was not made clear whether the computer systems included software, but at that time, even delivery of a complete computer hardware package was unusual.) By 1971, the Minsk Factory was said to be one of several computer factories that guaranteed the reliable operation of their products for 1 year.[17] This guarantee was not highly regarded, however, since it was also charged that the parts wore out and became useless after a year and a half.[18]

In 1971, upon the advice of the Minsk Factory, a computer center to service Minsk computers was established in Riga, with the active support of the Latvian Gosplan. The Riga Computer Center was "brought about due to the absence of a precise system for the introduction and utilization of computers."[19] According to an agreement with the Latvian government, the technical execution of the computer service center in Riga is strictly at the discretion of the Minsk Factory and according to its initiative, with no Soviet government plans or budgetary allocations involved. To establish such centers elsewhere would involve appropriate decisions by the Ministry and Gosplan.[20]

But not all runs smoothly at the Minsk Factory. Although the Minsk-32 was awarded the government's Mark of Quality,[21] the plant

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[16] Wade B. Holland, "Analysis" accompanying "Manufacturer's Responsibility for Introduction of Computers," *Soviet Cybernetics: Recent News Items*, Vol. 3, No. 1, January 1969, pp. 8-9.

[17] The other factories named were the plants at Kazan', Penza, and Ryazan'.

[18] M. Davidzon, "EVM zhdut spetsialistov" ["Computers Wait for Specialists"], *Sotsialisticheskaya industriya*, December 25, 1971, p. 2.

[19] I. Novikov, "Pust' mashiny dumayut luchshe" ["Let the Machines Think Better"], *Pravda*, July 27, 1971, p. 2; translated under the title "Central Servicing for Minsk Computers Tried," *Soviet Cybernetics Review*, Vol. 1, No. 6, November 1971, p. 15.

[20] Ibid., p. 17.

[21] "EVM poluchila znak kachesta" ["A Computer Has Won the Mark of Quality"], *Pravda*, January 3, 1972, p. 2.

has been criticized because one of the units it delivered fell far short of a complete configuration as specified by design and advertising data.[22] And at the same time that A. A. Reut, Director of the Factory since 1969, maintained that his organization had not received a complaint in 2 years, *Pravda* published the results of its investigation of problems at the Minsk Factory.[23]

Moscow Calculating and Analytical Machines (SAM) Plant

The Moscow Calculating and Analytical Machines (SAM) Plant is another major plant under the Ministry of the Radio Industry. The first Soviet computer to be produced industrially, the Strela, went into serial production at the Moscow SAM Plant in 1953. The Strela was developed at the Institute of Mechanics and Instrument Design of the Ministry of the Radio Industry by Yu. Ya. Basilevskii, who also designed the Ural-1. (See "Penza Calculating and Analytical Machines (SAM) Plant," below.)

The M-20 computer was also produced at this plant, beginning in 1959. The M-20 was designed by S. A. Lebédev and M. K. Sulim, then at the Moscow SAM Plant. As this factory tooled up for the next machine in the series, production of the M-20 was transferred to other plants under the Ministry of the Radio Industry (perhaps to a plant in the Volga region).[24]

The best-known scientific computer, the BESM-6, was also produced here. The BESM-6 was designed by Lebedev at the Institute of Precise Mechanics and Computer Engineering under the USSR Academy of Sciences. Both the designer and the manufacturer received a State Prize for this work. Serial production of the BESM-6 began in 1966, but less than a dozen are believed to have been built.[25]

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[22] Wade B. Holland, "Computer Users Catalog Their Problems," *Soviet Cybernetics Review*, Vol. 2, No. 4, July 1972, p. 13.

[23] "Quality Control Increases Minsk Output," *Soviet Cybernetics Review*, Vol. 2, No. 6, November 1972, pp. 37 and 39.

[24] Rudins, op. cit., p. 14.

[25] Ibid., p. 17.

Penza Calculating and Analytical Machines (SAM) Plant

The factory at Penza, the home of the Ural line, is one of the oldest and most important manufacturers of computers. It has been known for many years as the Penza Calculating and Analytical Machines (SAM) Plant. In 1968, an article referred to the VEM (Electronic Computing) Factory.[26] It is not known whether the Penza SAM Plant has changed its name or whether this is a different plant. It is possible that the plant changed names after its reconstruction on the same site during the 1959-1965 Seven-Year Plan. It is also possible that there are two separate plants, since the Iskra-110 keyboard computer (a project under the supervision of Minpribor) was reportedly produced by the Penza Computer Factory.[27] The author was not able to resolve the discrepancy from the available information.

Industrial production of one of the early computers, the Ural-1, began in 1955 at the Penza SAM Plant. The basic design work for the Ural-1 was done by Yu. Ya. Basilevskii of the Institute of Mechanics and Instrument Design of the Ministry of the Radio Industry. The product engineering group at Penza, headed by B. I. Rameev, who worked with Basilevskii in designing the Ural-1, designed the Ural-2 in 1958 and the Ural-4 in 1960.[28]

The first Soviet series of compatible computers--the Ural-11, Ural-14, and Ural-16--was also designed by the product engineering group at Penza in the early sixties. Design of the Ural-11 and -14 machines was completed in 1963, and both machines went into serial production in 1964-1965. Approximately 100 Ural-11s and 200 Ural-14s have been manufactured. A Ural-16 prototype was completed in 1965 and it was scheduled for serial production in 1967; however, as of 1972, Ural-14 computers were still being produced at the plant, but there was no evidence of the scheduled Ural-16s.[29]

The ES-1050 computer, one of the two Ryad machines to be

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[26] "Translation Editor's Note" to "Penza," in the magazine *NTO SSSR* [*Scientific and Technical Societies of the USSR*], No. 8, 1967, p. 10; translated in *Soviet Cybernetics: Recent News Items*, No. 13, January 1968, p. 21.

[27] Photo caption in *Izvestiia*, October 20, 1971, p. 5.

[28] Rudins, op. cit., p. 9.

[29] Ibid., p. 21.

manufactured exclusively by the Soviet Union,[30] is now being produced at the Penza Plant,[31] suggesting an important role for that plant in the Ryad work.

Elektron Plant (Erevan, Armenia)

Both the Razdan and Nairi computers intended for solving engineering, scientific, and economic problems have been produced by the Elektron Plant in Erevan. The Razdan-2 was the first semiconductorized computer in the Soviet Union. It has been succeeded by a Razdan-3 model, which is now serially produced.[32]

The Nairi series of computers was designed by the Erevan Scientific Research Institute of Mathematical Machines. Both the developers and the manufacturers of the Nairi series were awarded a 1971 State Prize. The recipients included G. E. Ovsepyan, Section Chief at the Erevan Scientific Research Institute of Mathematical Machines, Project Manager S. A. Tymanyan, Director of the Erevan Elektron Plant, and A. V. Zakirov, Chief of the Special Design Bureau for Computers at the plant, among others.[33]

In 1972, it was announced that the Nairi-3-1 third-generation, integrated-circuit computer would go into production at the Elektron Plant the following year.[34] A photograph taken in 1973 shows this new computer being checked out at the Baku Radio Factory in Azerbaijan.[35] On the other hand, however, it also appears that the All-Union computer effort enjoys some priority over regional efforts at producing locally designed computers. Production of the ES-1030 is also carried out at the Elektron Plant thus displacing, though not entirely eliminating, the regionally originated activities.

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[30] The other Ryad machine being manufactured exclusively by the Soviet Union is the ES-1020, although it was developed with the help of Bulgarian specialists.

[31] Holland, "Unwrapping the ES Computers," op. cit., p. 17.

[32] Rudins, op. cit., p. 33.

[33] "Nairi Wins State Prize," *Soviet Cybernetics Review*, Vol. 2, No. 2, March 1972, p. 5.

[34] "Nairi-3-1," *Soviet Cybernetics Review*, Vol. 2, No. 5, September 1972, p. 12.

[35] "Nairi-3 in Production Checkout," op. cit., p. 30.

PLANTS UNDER THE MINISTRY OF INSTRUMENT CONSTRUCTION, MEANS OF AUTOMATION, AND CONTROL SYSTEMS (MINPRIBOR)

The April 1966 resolution of the Central Committee of the CPSU and the Council of Ministers of the USSR charged the Ministry of Instrument Construction, Means of Automation, and Control Systems (Minpribor) with the development and production of control and specialized machines, programmed devices, and other automation hardware for the control systems for technological processes. Minpribor was also ordered to set up territorial design-installation offices to develop automated control system projects, complete the work of assembly, debugging, and installation, and later to repair the hardware of these systems.[36]

Production facilities under the control of Minpribor include the Kiev Electronic Computer and Control Machines (VUM) Plant; the Leningrad Electromechanical Plant; the Kursk Calculating Machines Factory; the Orlov Control Computer Plant; the Ryazan' Calculating-Analytical Machines Plant; the Smolensk Small Computer Plant; the Severodonetsk Computer Factory; the Tomsk Mathematical Machines Plant; and seven plants under the Sigma Association of Calculation and Organizational Equipment Enterprises in Lithuania. The seven Sigma Association plants are the Vilnius Calculating Machines Plant; the Tel'shyai Calculating Machines Plant; the Vilnius Electric Meters (or Electro-Calculating Machine) Plant; the Panevezhis Precision Machinery Plant; the Taurage Calculating Machine Assemblies Plant; the Pabrade "Modulis" Calculating Instruments Plant; and the Kaunas Experimental Automation Equipment Plant.

Kiev Electronic Computer and Control Machines (VUM) Plant

The Kiev Electronic Computer and Control Machines (VUM) Plant is one of the most important production facilities under Minpribor. The plant was established in 1963, and in 1965 began production of the Dnepr-1, designed by the Computer Center of the Academy of

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[36]"The Introduction of Computer Hardware and Automated Control Systems into the National Economy," *Soviet Cybernetics: Recent News Items*, No. 1, February 1967, pp. 56-57.

Sciences of the Ukrainian SSR. By 1968, the Dnepr-2 complex had been jointly developed by the Kiev VUM Plant and the Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR, the successor of the Computer Center. In this connection, it is interesting to note that the Kiev VUM Plant seems to enjoy an unusually close relationship with the Institute of Cybernetics (under the direction of Academician V. M. Glushkov), which designs most of its products.

A 1970 article in *Ekonomicheskaya gazeta* illustrates this partnership with examples.[37] The article says that when the working drawings for a particular computer are finished, "the institute's scientists . . . leave their offices and move to the plant, where they work with the engineers and technologists, until the first industrial series is produced." The article continues:

> Sometimes the creative efforts of both groups are interconnected to such an extent that it becomes difficult to determine who deserves credit for the development--the Plant or the Institute. This was the case with the Dnepr-2 computer. It was developed by 250 plant specialists and 25 scientific associates. The software was developed by 150 persons from the Institute, and 20 persons from VUM.[38]

The Dnepr-2 complex was the first computer system in the USSR for large-scale automation of industrial enterprises of various sizes and in various areas of industry. According to the article cited above, the computer "can play the role of an accountant, economist, statistician, pilot, dispatcher, or simply a mathematician."[39]

In 1969, a brochure published by the Minpribor announced the production of the Mir-1 computer, also developed by the Institute of Cybernetics in Kiev. The Mir was intended to be used for engineering

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[37] N. Dolotin, "Elektronnyi inzhener" ["An Electronic Engineer"], *Ekonomicheskaya gazeta*, No. 9, 1970, p. 15; excerpts translated under the title "The VUM Plant," *Soviet Cybernetics Review*, Vol. 4, No. 5, May 1970, pp. 17-20.

[38] Ibid., p. 18.

[39] Ibid., p. 19.

calculations in design bureaus and scientific research organizations.[40] In 1970, the Mir-1 was awarded the Mark of Quality.[41] The Mir-2, introduced in 1971, was also designed by the Institute of Cybernetics in Kiev, with new features for wider application in the national economy.

A 1971 article in *Pravda* also mentions work on other computers and control machines.[42] Some electronic machines developed by engineers of the Kiev Plant's Special Design and Planning Bureau are used to automate and control computer assembly in the plant itself. One such computer, the Kashtan, was developed for use in many branches of light industry.

The most recent efforts of the Kiev Plant are aimed at production of some of the machines in Minpribor's newest computer series, the ASVT (Modular System of Computer Hardware). The plant is believed to be the site of production for the M-2000, M-3000, and M-4000 machines. The M-2000 and the M-3000 are both machines in the ASVT-D (Modular System of Computer Hardware based on discrete elements) line, and were designed by the Severodonetsk Scientific Research Institute for Control Computers. The M-4000, a machine in the ASVT-M (Modular System of Computer Hardware based on microelectronics) line, is thought to have been designed by the Institute of Cybernetics in Kiev. The M-4000, a third-generation, integrated-circuit computer, is intended for use in automated control systems in various branches of the economy.

Leningrad Electromechanical Plant

The Leningrad Electromechanical Plant is now regarded as one of the main producers of special-purpose computers and devices (along with the Tomsk Mathematical Machines Plant, the Tbilisi Experimental

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[40] "The Mir Computer," *Soviet Cybernetics: Recent News Items*, Vol. 3, No. 2, February 1969, p. 11.

[41] V. Burlai, "U sozdateli elektroniki" ["The Developers of Electronics"], *Pravda*, January 19, 1971, p. 1.

[42] Ibid.

Plant of Control Computers, and the Tbilisi General-Purpose Plant). However, only 36.6 percent of the total production of these plants will be devoted to special-purpose computers and devices during the current Five-Year Plan (1971-1975). The present low-production capacity of these plants limits the output to "no more than two-fifths of the requirements of the national economy for special-purpose computers and numerical program-control devices for the 1971-1975 period.[43] The low technological level of the plants is also said to be a factor limiting the series production of special-purpose computers.

In 1967, the Leningrad Electrical Machines Plant began to produce the UM-1-NKh Computer, "intended for the control of production processes in various branches of Soviet Industry."[44] This machine (not to be confused with the UM-1 designed in Severodonetsk) was designed jointly by the USSR Ministry of the Electronics Industry and Minpribor. In 1969, V. V. Inkinen, Director of the Leningrad Electromechanical Plant, and others in the plant, as well as F. G. Staros and his design group, were awarded the State Prize for the development of the UM-1-NKh control computing complex.[45]

Kursk Calculating Machines ("Schetmash") Factory

The Kursk Calculating Machines Factory is one of several under Minpribor that produce the most important type of electronic keyboard calculators, the Iskra series. These machines are used to execute accounting-statistical, planning-economic, design, and engineering-mathematical calculations. However, this major line of keyboard

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[43] G. A. Gegeshidze and A. M. Shapiro, "Low Output of Control Computers Documented," translation of excerpts from "Prospects of Technical Rearming of the Branch Producing Special-Purpose Computers and Numerical Program-Control Devices" ("O perspektivakh tekhnicheskogo perevooruzheniya otrasli po proizvodstvu spetsializirovannykh EVM i ustrojstv chislovogo programmnogo upravleniya"), *Instruments and Control Systems* (*Pribory i sistemy upravleniya*), No. 3, 1972, p. 3, in *Soviet Cybernetics Review*, Vol. 2, No. 6, November 1972, p. 48.

[44] Rudins, op. cit., p. 39.

[45] "State Prizes Awarded," *Soviet Cybernetics Review*, Vol. 4, No. 1, January 1970, p. 46.

computers was criticized in 1971 by the director of the Kursk Factory as being "far from perfected," particularly with regard to its technological base.[46]

The Iskra, Iskra-12, the Iskra-12M, the Iskra-22, the Iskra-112P, and the Iskra-122 are all models of the Iskra series that have been produced by the Kursk Factory. The original Iskra machine was developed jointly by the Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR in Kiev and the Kursk Calculating Machines Factory. A later model, the Iskra-12, was developed by Moscow and Leningrad engineers. The Iskra-12M machine, developed around 1971 at Kursk, is said to be faster, smaller, and more reliable than the Iskra-12 machine. However, the Iskra-12 was scheduled to be replaced in 1972 by the Iskra-122, jointly developed by Leningrad engineers and the Design Bureau of the Kursk Factory.

The Iskra-122 calculator is used by research and planning-design organizations and enterprises for engineering, technical, and simple scientific problems.[47] A model of the machine was developed in Leningrad with the participation of a group of engineers and technicians from the Kursk Factory. But when the models and the circuits reached the factory, it was discovered that the circuits had many failures. The staff of the Kursk Factory cooperated with the modeling department of the unnamed design bureau (presumably in Leningrad) in debugging the machine.[48] In 1972, a *Tass* report announced that the first units of the Iskra-122 had been produced at the "Schetmash" (Calculating Machines) Factory in Kursk.[49]

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[46] Wade B. Holland, "Commentary" to "Iskra Keyboard Calculators," *Soviet Cybernetics Review*, Vol. 1, No. 5, September 1971, p. 40. (This critical comment appeared in an article in the newspaper *Socialist Industry*, June 2, 1971.)

[47] Ibid., p. 38.

[48] Yu. Antropov, "S dnem rozhdeniya" ["Happy Birthday"], *Sotsialisticheskaya industriya* [*Socialist Industry*], November 14, 1971, p. 1; translated under the title "Trouble-Shooting the Iska-122 [*sic*] IC Calculator," *Soviet Cybernetics Review*, Vol. 2, No. 3, May 1972, pp. 78-79.

[49] "Iskra-122 in Production," *Soviet Cybernetics Review*, Vol. 2, No. 4, July 1972, p. 34.

Another machine in the Iskra series, the Iskra-22, also seems to have been designed by Leningrad engineers and the Design Bureau of the Kursk Calculating Machines Factory. The Iskra-22 was scheduled to be replaced in 1972 by a new model based on integrated circuits, the Iskra-112P. The Iskra-112P was apparently developed by the Kursk Factory on its own around 1971-1972.

According to a Soviet source, "the Iskra-11 [manufactured by the Orlov Control Computer Plant], Iskra-12, and Iskra-22 have identical operating characteristics, and are based on standard Mir-1 functional elements."[50] The Mir-1 was designed by the Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR in Kiev, which participated in the design of the original Iskra model.

Orlov Control Computer Plant

The Orlov Control Computer Plant is another factory under the direction of Minpribor which produces some models of the Iskra control computers. In 1973, the Orlov Plant was said to be "one of the foremost manufacturers of small computing equipment, specializing in modern, compact devices based on microelements."[51]

The Orlov Plant began operation in January 1969. Its first product was the Orbita calculator.[52] It also manufactured the Iskra-12 electronic accounting machine, which was designed by Moscow and Leningrad engineers.[53] In 1970, the Orlov Plant began production of the Iskra-11 desk calculator, designed for accounting, planning, statistical, and engineering calculations.[54] The Iskra-11 has operating characteristics identical to the Iskra-12 and Iskra-22 (manufactured by the Kursk Calculating Machines Factory), all of which "are based on

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[50] "Iskra Keyboard Calculators," op. cit.

[51] "Computer Plant in Orlov," *Soviet Cybernetics Review*, Vol. 3, No. 2, May 1973, p. 5.

[52] Ibid.

[53] "Pomochet 'Iskra'" ["With the Aid of Iskra"], *Ekonomicheskaya gazeta*, No. 11, March 1969, p. 6.

[54] "Elektronnaya Iskra" ["The Electronic Iskra"], *Ekonomicheskaya gazeta*, No. 31, 1970, p. 22.

standard Mir-1 functional elements."[55] As noted earlier, the Mir-1 was designed by the Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR in Kiev, which also participated in the design of the original Iskra model. In 1971, Orlov began to produce the more advanced Iskra-111, expected to replace the Iskra-11.[56]

Some of the organizational problems of the Soviet computer industry are illustrated in a 1973 article in *Pravda*.[57] When a customer in the Soviet Far East received a defective Iskra-11M from the Orlov Plant, he was referred by the plant's chief engineer to an installation and debugging trust in Krasnogorsk in Moscow Oblast. Much later, an official at Minpribor wrote the customer that, according to a new order, the Omsk Sibavtomatika Trust was responsible for the repair of keyboard computers in Siberia and the Far East. The customer reported to *Pravda* that almost a year and a half after the machine was received, it was still idle. The author of the article suggested that the customer calculate his losses due to the computer's idle time and submit a bill to "those who are to blame for this red tape."

Ryazan' Calculating-Analytical Machines (SAM) Plant

A third plant that has produced an Iskra machine is the Ryazan' Calculating-Analytical Machines Plant. This plant developed, and is serially producing, the Iskra-23 calculating machine. The Iskra-23 is used for engineering and economic calculations.[58]

Earlier devices produced by the Ryazan' Calculating-Analytical Machines Plant include: electronic machines for data processing in bookkeeping institutions and banks;[59] a punchcard calculator used to

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[55]"Iskra Keyboard Calculators," op. cit.

[56]Ibid., pp. 38, 40.

[57]G. Yakovlev, "EVM v meshke" ["A Computer in a Bag"], *Pravda*, March 18, 1973, p. 2; translated under the title "A Bill for Red Tape," *Soviet Cybernetics Review*, Vol. 3, No. 4, July 1973, pp. 47-48.

[58]"Iskra Keyboard Calculators," op. cit., p. 37.

[59]"Tol'ko fakty" ["Only the Facts"], *Izvestiia*, September 17, 1967, p. 6.

determine the strength of railroad embankments or concrete bridge supports erected on frozen ground;[60] the "Meshchera" calculating machine;[61] and the serially produced papertape reader FSU-1, based on photodiodes. The FSU-1 reader, however, was said to have "a number of significant shortcomings."[62]

The PL-20 perforator is another piece of computer equipment that has been serially produced by the Ryazan' Plant,[63] presumably after approval by a governmental interagency commission designated to evaluate the machine. In an article published in *Pravda* criticizing the operational unreliability of computer hardware, two Soviet engineers made specific mention of the PL-20 perforator as an unreliable machine, but found it difficult to determine who should be held responsible for approving its serial production.[64] The implication clearly was that had stricter standards of quality control been in effect, the machine would never have been produced.

In early 1967, the Ryazan' Calculating-Analytical Machines Plant was involved in an interesting controversy regarding advertising of the VA-245MK alphabetic-computational (factoring) machine. Customers who ordered the machine from the factory (including the Central Statistical Administration of the USSR) received letters saying that the factory did not produce the item advertised. Who was responsible for the advertisement? The factory director claimed that the Moscow Institute of Electronic Control Computers had placed the ad

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[60] Ibid., January 27, 1968, p. 6.

[61] Photo caption in *Izvestiia*, March 6, 1968, p. 1.

[62] "Five Soviet Papertape Readers," *Soviet Cybernetics: Recent News Items*, Vol. 3, No. 2, February 1969, p. 93.

[63] "No Papertape Copiers," *Soviet Cybernetics: Recent News Items*, No. 9, October 1967, p. 7; taken from "Ustrojstvo dlya dublirovaniya perfolenty" ["A Unit for Reproducing Papertape"], by V. V. Korolev, in *Avtomatika, telemekhanika, svyaz'*, No. 8, 1967, p. 41.

[64] O. Godliba and V. Skovorodin, "Nenadezhny po 'traditsii'" ["Unreliable by 'Tradition'"], *Pravda*, August 27, 1967, p. 3; translated and summarized in *Soviet Cybernetics: Recent News Items*, No. 8, September 1967, p. 36.

without the plant's approval, but the newspaper publishing this story (which had also run the ad) blamed the Ryazan' Plant.[65]

By 1971, the Ryazan' Plant was said to be one of several guaranteeing their products for one year.[66] However, since the parts usually wore out after a year and a half, this guarantee was almost worthless.[67]

Smolensk Small Computer Plant

A fourth manufacturer of one of the Iskra models is the Smolensk Small Computer Plant. Manufacture of the Iskra-110 table-model computer began in 1972, scheduled for a production rate of several hundred units per year.[68] The machine is designed for accounting, statistics, planning, and other business computations.

The Smolensk Plant produced an earlier (1969) electronic calculating machine, the "Solotcha." This machine was intended for mechanizing initial accounting and planning information.[69]

Severodonetsk Computer Factory

The Severodonetsk Computer Factory produces the UM-1 control computer, developed by the Scientific Research Institute for Control Computers, located in Severodonetsk (Ukraine). An earlier product, the Promin'-M, was designed by the Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR in 1967, and was then serially produced at Severodonetsk. The Ukrainian Institute of Cybernetics, the Severodonetsk Computer Factory, and the Severodonetsk

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[65] "Vot tebe, babuska, i mashinka!" ["For You, Babushka, Get a Typewriter!"], *Ekonomicheskaya gazeta*, No. 8, February 1967, p. 46.

[66] The other factories named were those at Minsk, Kazan', and Penza.

[67] Davidzon, op. cit., p. 2.

[68] "EVM dlya bukhgaltera" ["A Computer for the Accountant"], *Sotsialisticheskaya industria*, September 7, 1972, p. 2.

[69] "Schitact mashina" ["A Machine Counts"], *Pravda*, January 8, 1969, p. 6.

Scientific Research Institute of Control Computers all appear to work together in close cooperation.[70]

Tomsk Mathematical Machines Plant

The Tomsk Mathematical Machines Plant is now said to be one of the main producers of special-purpose computers and devices.[71] It is not known when this plant began production, but automation was introduced in 1968.[72] One of its products is the Sever-2 computer, used to control typesetting.[73]

Sigma Association of Calculating and Organizational Equipment Enterprises (Lithuania)

The Sigma Association of Calculating and Organizational Equipment Enterprises consists of three design bureaus and seven plants in Lithuania, all producing computers and related equipment. The Sigma Association is a Main Administration of Minpribor and, unlike other Main Administrations under this ministry, it is a territorial division rather than an administrative division. It was the First Main Administration to operate on a cost-accounting basis (as of July 1, 1966).[74]

The work of the Sigma Association is guided by a council of directors. The Association chief, two of his deputies, and the directors of the seven enterprises and three design bureaus all serve on the council of directors. According to an article published in

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[70]Rudins, op. cit., p. 29.

[71]For further details, see the discussion of the Leningrad Electromechanical Plant on p. 104, above.

[72]"Gorizonty reformy" ["Horizontal Reforms"], *Izvestiia*, January 18, 1965, p. 5.

[73]"Dlia knizhnogo konveyera" ["For Book Production"], *Pravda*, July 24, 1969, p. 6.

[74]"Cost Accounting Successful in Sigma Association of Calculating and Organizational Equipment Enterprises," *USSR Industrial Development, Electronics and Precision Equipment*, No. 26, JPRS 41,670 (Joint Publications Research Service, TT:67-32302), pp. 1-2, July 1, 1967.

Ekonomicheskaya gazeta by A. Chuplinskas, the Chief of the Sigma Association, the council "makes important decisions on current and long-range problems of the activities of the association."[75] Some social problems are decided with the help of the chairmen of the plant union committees.

The rate of growth of production sales and the level of profitability of production for the Association remain stable, but these vary for individual enterprises because of "reconstruction of the old and the mastering of new capacities, changes in products and prices connected with them in the expansion of specialization, and the removal of bottlenecks."[76] All the directors of the enterprises and the chiefs of the design organizations are "morally and materially interested in increasing the efficiency of production of the whole association."[77] Under the cost-accounting procedures described, it is claimed that the managers of the enterprises have "maximum independence."[78] Chuplinskas says that at the present time, the number of personnel and amount of expenditures for maintenance of the apparatus of the Association are determined from above, but he advocates letting the council of directors determine these figures, because "those above do not always see everything."[79]

Certain flaws in the optimistic report by Chuplinskas are pointed out in an article by V. Koval', Chief Engineer of the Sigma Association, in the same issue of *Ekonomicheskaya gazeta*. In particular, he discusses problems of technical services and design. "To improve coordination of the activities of the technical sub-divisions of the association and to raise the level of engineering policies," an engineering council of the Main Administration was formed.[80] The engineering council includes the chief engineers and chief specialists of

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[75]Ibid., p. 3.

[76]Ibid.

[77]Ibid.

[78]Ibid., p. 5.

[79]Ibid., p. 6.

[80]Ibid., p. 7.

the enterprises and designing organizations, representatives of the Kaunas Polytechnical Institute and a number of institutes of the Academy of Sciences of the Lithuanian SSR.

The technical services of the Sigma Association have participated in many changes within the Association itself. They have implemented many measures in the enterprises for the mechanization and automation of production and auxiliary processes.[81] They have also worked on the scientific organization of labor (NOT),[82] on more progressive norms of material expenditure, and on improvement in the quality of production. To help raise the operational reliability of the Association's products, the technical services also "are holding conferences with clients, sending them questionnaires about the behavior of the equipment in operation, making personal investigation into the experimental operation of the first industrial groups, and training servicing personnel."[83] The technical services are now concentrating on developing complete units for production control. They are not compiling time-consuming documentation on technological or engineering processes, or on the organizational preparation for production, because they have found it possible to prepare for production of new equipment from the preliminary recommendations of the developers.[84] However, they are not able to prepare and test several variants of experimental models, since the design organizations do not have a strong experimental base. Sometimes they cannot even prepare a single model on time.

Koval' goes on to say that in contrast to the interaction of the enterprises, the Association's influence on its design bureaus is quite limited. The subjects for design are determined by the Sigma Association, but the economic-planning indicators are set by Minpribor, and frequently there is a conflict. Because of this situation, the development rate of new equipment is artificially held back. Koval' recommends that the Association itself establish such things as volume

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[81] Ibid., p. 8.

[82] Soviet jargon for "scientific management."

[83] "Cost Accounting Successful in Sigma Association . . .," op. cit., p. 8.

[84] Ibid.

of work, limits on the acquisition of equipment, inventories, and so on for the design bureaus, as it does for the enterprises.[85] Koval' attributes the Association's limited influence on the planning-design organizations to the fact that the existing statutes regarding bonuses to workers of these organizations do not yet conform to the new conditions of cost-accounting applicable to the enterprises.

The three design bureaus of the Sigma Association are the Special Design Bureau for Computing Machines; the Special Design Bureau for Organizational Technology; and the Special Planning and Design Bureau for Management Systems.[86] The seven enterprises of the Sigma Association are the Vilnius Calculating Machines Plant; the Tel'shyai Calculating Machines Plant; the Vilnius Electric Meters Plant (or Electro-Calculating Machine Plant); the Panevezhis Precision Machinery Plant; the Taurage Calculating Machine Assemblies Plant; the Pabrade "Modulis" Calculating Instruments Plant; and the Kaunas Experimental Automation Equipment Plant.

Vilnius Calculating Machines Plant. The Vilnius Calculating Machines Plant was established in 1952 and has been doing work on NOT since 1961. In 1966, under the guidance of the plant's Section for the Introduction of Computing Technology, and with the help of the Computer Center of the Latvian State University, the enterprise mechanized dynamic planning operations with the aid of a computer. The following year, the Section introduced a Ruta complex to mechanize and automate production administration. They also planned, in the near future, to introduce a management system using the Ruta computer complex to collect information on deviations from the norm.[87] In 1970, it was announced that "the Ruta-110 computer complex, intended for automatic production control systems and developed by the Lithuanian Sigma Association, will be put into operation this year at the Vilnius Computer Plant."[88]

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[85] Ibid., p. 9.

[86] For further details, see Section IV, p. 87.

[87] "Upravlenie proizvodstvom," *Ekonomicheskaya gazeta*, No. 23, June 1967, p. 10; excerpted in *Soviet Cybernetics: Recent News Items*, No. 6, July 1967, pp. 86-87.

[88] "Computing Equipment," *Soviet Cybernetics Review*, Vol. 4, No. 4, April 1970, p. 43.

In 1971, an article in *Sotsialisticheskaya industriya* predicted that completion of the second phase of the construction of the Vilnius Calculating Machines Plant would aid the development of a unified system for producing computing equipment. In 1972, an article in *Pravda* mentioned that the Vilnius Calculating Machines Plant would be justifiably regarded as an advanced enterprise, but that inefficiencies in support services were draining its resources.

One product of the Vilnius Calculating Machines Plant is the ATE-80 electronic printer for economic data processing. The ATE-80 was designed by the Scientific Research Institute of Calculating Machine Construction (NIISchetmash) in 1961-1962. However, an experimental model of the machine did not undergo interagency testing until 1965-1966, and the ATE-80 was not put into serial production until 1967.[89]

In 1969, the Ruta-701 automatic reader for direct reading of data recorded on numerical-entry forms was mentioned in an introduction to the Russian-language translation of an American book.[90] This machine, developed by the Special Design Bureau at the Vilnius plant, has already been tested and is now being serially produced at the plant.

Production of the prototype of the M-5000 third-generation computer began at the plant in 1973, according to V. Matulyauskas, head of the planning department of the plant. The machine's production was to have been organized according to individual units. While organizing the production of the M-5000, the plant was to continue its regular serial production. The M-5000 is intended to be used for "the most complex economic calculations."[91]

Tel'shyai Calculating Machines Plant. The production of unitized perforators was started in 1968 in the newly constructed main building for the Tel'shyai Calculating Machines Plant located on the eastern

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[89] Rudins, op. cit., p. 6.

[90] R. Wilson, *Opticheskie chitayushchie ustrojstva* [*Optical Page-Reading Devices*] (Moscow: Mir Publishing House, 1969), p. 6; discussed in "Ruta-701 Optical Reader in Serial Production," *Soviet Cybernetics Review*, Vol. 3, No. 10, October 1969, p. 7.

[91] "M-5000 in Production," *Soviet Cybernetics Review*, Vol. 3, No. 2, March 1973, p. 5.

outskirts of Tel'shai, Lithuania. According to a 1968 article in *Ekonomicheskaya gazeta*, "when a second building complex is completed the enterprise will become one of the largest specialized plants in the country for the production of punchcard equipment."[92] A 1967 article in *Ekonomicheskaya gazeta* related that communists of the Sigma Association, including the chiefs of the divisions of engineering, "helped the communists of the Tel'shyai Calculating Machines Plant raise the quality of the assembly of the punch assembly of the perforating machines and accelerate the completion of equipment for the information-computing center of the planning-design bureau design systems."[93]

Vilnius Electric Meters Plant (or Electro-Calculating Machine Plant). This plant has been in operation since 1965 at least, but not much is known about its activities. A 1968 photograph in *Ekonomicheskaya gazeta* shows an automatic unit for processing drums of counter devices produced by this plant.[94] By 1969, according to the plant's director, V. Pashkevichus, the plant had not been producing its main product (unnamed) for a year.[95]

One of the products of the plant is the Vil'nyus keyboard computer. In 1967, a customer received five of these machines, which were repaired by mechanics from the factory several times within a short period. The head of the Sigma Association, A. Chuplinskas, wrote a letter to the *Izvestiia* Editorial Board, stating that these Vil'nyus computers were "idled because of gross violation of the operation instructions." He further stated: "A resolution has been

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[92] "Iz soyuznykh respublik . . ." ["From the Union Republics . . ."], *Ekonomicheskaya gazeta*, No. 31, August 1968, p. 3; excerpted in *Soviet Cybernetics: Recent News Items*, No. 21, September 1968, p. 112.

[93] "Cost Accounting Successful in Sigma Association . . .," op. cit., p. 18.

[94] "Rotornyj avtomat" [photograph], *Ekonomicheskaya gazeta*, No. 4, January 1968, p. 45; mentioned in *Soviet Cybernetics: Recent News Items*, No. 14, February 1968, p. 95.

[95] "Cost Accounting Successful in Sigma Association . . .," op. cit., p. 15.

adopted on the development of a more reliable keyboard machine. It will go into production this year [1967]."[96]

In 1970, the Vilnius Electric Meters Plant announced the Rasa desk computer, designed for bookkeeping, accounting, statistical, engineering, and other calculations. The machine weighs 22 kilograms.[97]

Panevezhis Precision Machinery Plant. A new production building was being constructed at the Panevezhis Precision Machinery Plant in 1967. When problems were incurred in its construction, the Sigma Association's Party Bureau ordered the Association's chief of the division of capital construction to give assistance. The repair-construction shops of all of the enterprises of Sigma Association sent bricklayers, plasterers, and carpenters to Panevezhis. The shop delivered its first product in a month.[98] It would appear that not all the construction problems were solved immediately, however. A 1971 article in *Sotsialisticheskaya industriya* states that

> At enterprises of the Sigma Association in Lithuania, it has been decided to cut in half the time needed for mastering the production of new computer models. The completion of construction of the Panevezhskij Plant of Precise Mechanics will aid the development of a unified system for computing equipment production.[99]

According to an article in *Ekonomicheskaya gazeta*, the new conditions of planning, adopted in 1966, together with new, more progressive engineering measures, made it possible for the collective of the Panevezhis Plant of Precision Machinery to produce almost twice the

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[96] "Mashiny ispravleny" ["Machines Corrected"], *Izvestiia*, May 30, 1967, p. 4; translated in *Soviet Cybernetics: Recent News Items*, No. 5, June 1967, p. 82.

[97] "Rasa Desk Calculator Announced," *Soviet Cybernetics Review*, Vol. 4, No. 9, November 1970, p. 12.

[98] "Cost Accounting Successful in Sigma Association . . .," op. cit., pp. 17-18.

[99] A. Tikhonov, "Sopryazhennost' informatsii" ["Union of Information"], *Sotsialisticheskaya industriya* [*Socialist Industry*], July 25, 1971, p. 2; excerpted under the title "Steps Taken To Coordinate IR Systems," *Soviet Cybernetics Review*, Vol. 1, No. 6, November 1971, p. 57.

number of devices for automatically registering information as were produced previously.[100]

Another product of the Panevezhskij Plant is the "Siluet" automatic graphic reader. In 1968, the plant announced that the "Siluet" was being serially produced. This machine is designed for automatically reading curves and output to papertape in international telegraph code No. 2, or binary code.[101]

Taurage Calculating Machine Assemblies Plant. Before 1966, the construction of lines at the Taurage Calculating Machine Assemblies Plant was being done with loans from Gosbank. Completion of these lines was expected to be protracted because of lack of material incentive on the part of the designers. Around 1967, the workers of the Sigma Association's Special Planning and Design Bureau for Management Systems planned and put into service at the plant a mechanized constant-flow line for the assembly and regulation of the RVM small relay. Under the new system of material encouragement within the Sigma Association, the workers of the Special Bureau knew that they will receive a bonus for all work considered excellent on the project.[102] The workers of the Special Design Bureau and at the plant also planned increased production facilities for the plant, including three new automatic machines that would release twenty-four men from one operation and result in a 15,000- to 20,000-ruble saving.

Other work in improving the plant's production conditions was initiated by the Party Bureau of the Sigma Association, which investigated a complaint about poor ventilation in the assembly section. Not only was the ventilation corrected, but the section was also rearranged and a conveyor was installed.

Pabrade "Modulis" Calculating Instruments Plant. As in the case of the Taurage Calculating Machine Assemblies Plant, the construction

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[100] Ibid., pp. 7-8.

[101] "Grafikoschityvayushchij avtomat" ["Automatic Graphic Reading Device"], *Ekonomicheskaya gazeta*, No. 47, November 1968, p. 47/1; excerpted in *Soviet Cybernetics: Recent News Items*, No. 24, December 1968, p. 98.

[102] "Cost Accounting Successful in Sigma Association . . .," op. cit., pp. 12-13.

of lines at the Pabrade "Modulis" Calculating Instruments Plant was done with loans from Gosbank prior to July 1966. This work was taken over by thé Sigma Association's Special Planning and Design Bureau for Management Systems. The Design Bureau designed, and put into service in the plant, "a conveyor line for assembling blocks of diodes and resistors."[103]

Communists of the Sigma Association's Party Bureau have also influenced production in the plant. Communists at the plant complained about the poor accounting records on the movement of materials and of unskilled repair of equipment. The Party Bureau ordered Sigma's chief bookkeeper to go to the Pabrade Plant and help the workers put order into the materials accounts. The chief of the division of the main Association, the secretary of the Party Bureau, and specialists of the division of technical control of the Vilnius Calculating Machines Plant tested machines at the Pabrade Plant for technical precision, regulated them, and taught this work to the Pabrade repairmen.[104]

Kaunas Experimental Automation Equipment Plant. Very little is known about this plant, except that it makes some electrographic equipment. The Sigma Association's conversion to new planning methods and to new, efficient engineering methods is said to have been responsible for the collective of the Kaunas Experimental Plant having mastered the output of electrographic equipment a year earlier than had been estimated.[105]

PLANTS OF UNKNOWN AFFILIATION

Besides the plants under the Ministry of the Radio Industry and Minpribor, there are a number of other computer factories, whose organizational subordination is unknown. Very little information about their activities has appeared in the press, although, in some cases, enough information has been given to stimulate speculation about their organizational affiliation.

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[103]"Cost Accounting Successful in Sigma Association . . ," op. cit.

[104]Ibid., p. 17.

[105]Ibid., pp. 7-8.

Middle Volga Sovnarkhoz

An unidentified plant in the Middle Volga Sovnarkhoz is named as the probable manufacturer of the base-3 Setun' computer, originally developed at Moscow University as a student design project. This machine was definitely serially produced at an unnamed city. A new set of interpretive systems was later developed at the Siberian Scientific Research Institute of Power Engineering to overcome its shortcomings.[106]

Orel Computer Plant

In 1967, it was announced that construction of a large plant for computing and control machines had begun on the northern outskirts of Orel.[107] The plant included a computer center, laboratories, a conference hall, housing, and service facilities. Part of the enterprise was expected to begin operation at the end of 1968.[108] Because the plant was intended for control machines, it may be speculated that this enterprise falls under Minpribor.

Pskov Radio Components Plant

The Pskov Radio Components Plant was not associated with computer production until August 1971, when a brief article in *Sotsialticheskaya industriya* announced that the K-200 had been accepted for quantity production there.[109] The name of the plant would seem to indicate that it operates under the jurisdiction of the Ministry of the Radio Industry.

The K-200 is something of a mystery machine. In January 1971, a brochure on the K-200 was published in English by the "Elektronika Institute." This previously unknown organization located in Kiev is

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[106] "Problems with Serially-Produced Setun'," *Soviet Cybernetics: Recent News Items*, No. 6, July 1967, p. 6.

[107] "Tol'ko fakty" ["Only the Facts"], *Izvestiia*, May 31, 1967, p. 4.

[108] "Khronika stroitel'nykh budnej," *Ekonomicheskaya gazeta*, No. 3, January 1968, p. 39; excerpted in *Soviet Cybernetics: Recent News Items*, No. 14, February 1968, p. 90.

[109] Wade B. Holland and Willis H. Ware, "K-200: Space Computer or Engineering Oddity?" *Soviet Cybernetics Review*, Vol. 2, No. 3, May 1972, p. 20.

assumed to be the machine's designer, but its jurisdictional affiliation was not given in the brochure.[110] A 1971 article in *Ekonomicheskaya gazeta* says that the computer is capable of controlling "the operation of an atomic reactor or technological processes at a single enterprise or at several related enterprises. The machine's 'brain' can store and analyze a tremendous quantity of data. The designers believe scientists, especially those dealing with economic forecasting, will certainly take advantage of this latter capability."[111]

Tbilisi Experimental Plant of Control Computers

The Tbilisi Experimental Plant of Control Computers appears to be a relatively new plant. As of 1972, the production of the Gelati-3 and Gelati-5 keyboard computers had begun at the Tbilisi Plant. These machines were developed by the Tbilisi Scientific Research Institute of Instrument Construction and Means of Automation. In 1968 and 1970, the computers were submitted for approval by "commissions." "The Gelati-3 computer is used for engineering, statistical, and accounting calculations. The Gelati-5 is used for accounting, economic, and statistical calculations."[112]

"Tochelektropribor" Enterprise (Kiev)

The "Tochelektropribor" Enterprise in Kiev, otherwise known as the Kiev Precision Electrical Appliances Factory, "produces about 20 measuring instruments and a small-scale arithmometer-type computer using multistable elements," according to an article in the English-language digest *Sputnik*.[113] "It is likely," says the author, "that

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[110] Ibid.

[111] "Elektronika K-200 in Production," *Soviet Cybernetics Review*, Vol. 2, No. 2, March 1972, pp. 5-6.

[112] "Gelati Computers," *Soviet Cybernetics Review*, Vol. 2, No. 3, May 1972, p. 48.

[113] Vyacheslav Demidov, "Multistable Element Design Claimed" (compilation of English-language articles in *Sputnik*, September 1970, pp. 52-53), *Soviet Cybernetics Review*, Vol. 4, No. 9, November 1970, p. 63.

some of the factory's electronic innovations will be used to improve large computers, too."[114]

One of the products of the Tochelektropribor Enterprise is the Ros' table-model keyboard calculator, developed at the Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR in Kiev. This computer was recommended for serial production in 1970. According to an article in *Izvestiia*, hundreds of Ros' calculators would be produced by the plant that year.[115]

As early as 1968, *Ekonomicheskaya gazeta* noted that the Tochelektropribor Enterprise was using computer hardware in production management, planning, and accounting.[116] A *Sotsialisticheskaya industriya* article in 1970 stated that the automatic control system at Tochelektropribor used the Minsk-22 computer as its basis. Four sets of punchcard equipment were also said to be in operation at the factory.[117]

The Tochelektropribor Enterprise was one organization of six named to receive second prize and a certificate of merit in the First Competition for Best Use of Computers, sponsored by the Ukrainian Republic Council of Scientific and Technical Societies during 1970.[118]

Ul'yanovsk Volodarskii Plant

The Ul'yanovsk Plant has generally produced the first few units of S. A. Lebedev's machines (Lebedev's Institute of Precise Mechanics and Computer Engineering is under the jurisdiction of the USSR Academy of Sciences). Further production of Lebedev's machines is then taken

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[114] Ibid.

[115] "Computing Equipment," *Soviet Cybernetics Review*, Vol. 4, No. 5, May 1970, p. 51.

[116] "Shagi khozyajstvennoj reformy," *Ekonomicheskaya gazeta*, No. 45, November 1968, p. 14; excerpted in *Soviet Cybernetics: Recent News Items*, No. 24, December 1968, p. 96.

[117] "Trofei progressa" ["The Trophy of Progress"], *Sotsialisticheskaya industriya*, February 12, 1970, p. 2.

[118] "Best Computer-Use Contest," *Soviet Cybernetics Review*, Vol. 2, No. 3, May 1972, p. 81.

over by other factories or NIISchetmash (Scientific Research Institute of Calculating Machine Construction).[119]

The Ul'yanovsk Plant has also been mentioned in *Pravda* in connection with problems encountered in the production of program-controlled machines. An article in the July 14, 1971 edition of *Pravda* stated that conditions were appropriate to produce program-controlled machines on a large scale at Ul'yanovsk, but that the proper accessory parts were not being produced by intermediate organizations, particularly ball couples. A second, unnamed plant assigned to manufacture program-controlled machines was not yet ready to begin production. *Pravda* reported that "The Ministry of Machine Building and Instrument Industry is asked to intervene and correct the lag in the production of program-controlled machines."[120]

From the above bits of information, it would appear likely that the Ul'yanovsk Plant was an experimental plant under the USSR Academy of Sciences which may have been taken over by Minpribor.

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[119]Rudins, op. cit., p. 14.

[120]"Staraya Model" ["An Old Model"], *Pravda*, July 14, 1971, p. 2.

VI. CONCLUSIONS

The structure and organization of the Soviet computer industry have gone through several major phases since the late 1940s when computers first attracted the attention of Soviet scientists. Each phase, however, has left its imprint on the present situation, and these cannot be ignored in evaluating the present and future state of the industry.

The earliest period (1948-1953) contributed a continuing ideological mistrust of computers in the form of the anticybernetics movement. This movement not only helped to retard the development of the early Soviet computer industry, but the suspicion it created has continued to impede progress even in the 1970s.

The second phase (1954-1965) was characterized by a proliferation of agencies involved with R&D and/or production of computer hardware. The precedent established during this period of lack of coordination among research, design, and production, and between the development of hardware and software, has persisted to the present, including the Ryad project, in spite of much criticism of this pattern of fragmented responsibility and some attempts to overcome it.

The most recent phase (1969 to 1974) is very likely not yet complete. There is important evidence that the Soviet government is attempting to centralize computer R&D in a more direct fashion than heretofore. This has been done through the decision to build the ES (Unified System) computers in cooperation with a number of Eastern European countries.[1] Furthermore, there are indications that the largest machine in an important indigenous Soviet computer series (ASVT-M) has been designed to tie in with the ES machines. Such Party-government attempts to centralize computer R&D and production have not included all the important leaders in the field nor have they supplanted entirely on-going work that so far has been relatively free from higher-level interference.

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[1]Bulgaria, Czechoslovakia, the German Democratic Republic, Hungary, and Poland.

No single barrier prevents the problems of the Soviet computer industry from being solved. Problem areas are too numerous, too interrelated, and too deeply entrenched for easy or quick solution.

Many of the problems of the Soviet computer industry are common to other Soviet industries. They reflect flaws in the planning and managerial structure of the Soviet economy in general. They include the long lag between the design of a particular computer and its introduction into the economy, laggard technology in the computer industry, poor production techniques, low production rates, and a lack of quality control. Other serious problem areas relate to the special nature of the product. These include a lack of commonality and compatibility between series of computers and often even within families of computers, incompleteness of the product (particularly in the way of software and peripherals), and low utilization rates of computers.

The long lag between the design and the production of a particular computer is typical of many other Soviet products, but it is especially troublesome in the computer industry, where a particular machine may become obsolete by the time it goes into production. The low level of technology in the computer industry is a reflection of the low level of technology in most areas of Soviet civil industry, particularly those (such as electronics) requiring high precision. It also indicates the comparative isolation of the Soviet computer industry, until recently, from the international computer market. Inferior production techniques are found in many other Soviet industries, but are an especially serious handicap when sophisticated, complex products such as computers are to be built. The production of computers will continue at a low rate until R&D problems are solved, and managerial and economic incentives are changed. Quality control, which has not been a strong point in most other Soviet industries in the past, must improve significantly if Soviet computers are to be useful enough to justify their costs.

Some problems peculiar to the computer industry have been ignored in the past and are being remedied very slowly if at all. The lack of commonality and compatibility among Soviet computers, their software, and related equipment has greatly constrained their usefulness. In the

United States, not only do many IBM machines feature commonality or compatibility, but also many smaller companies produce computers, peripherals, and other equipment that are compatible with the IBM products. Rectification of that lack in the Soviet Union will not be easy, since the number of computers produced (particularly the IBM-compatible ES series) is still smaller than needed, and since obsolete equipment is not ordinarily discarded for many years.

Soviet organizations producing computers, related equipment, and software are reluctant to assume responsibility for the integration of their products into a computer system that will meet the customer's needs. The only apparent exception involves the ES series computers. In the United States, in contrast, there is an increasing trend toward a systems approach; planning, from the outset, includes not only the hardware (including peripherals) and the software, but even the communications interfaces.

Low utilization rates of Soviet computers reflect their low reliability, the lack of adequate software, the lack of necessary peripherals and communications equipment, shortages of programmers and maintenance personnel, and bureaucratic jealousies.

Remedying such defects will require major changes in the operational methods of both the Soviet computer industry and the bureaucracy that controls it. In the past, such problems have been minimized by isolating important industries under one ministry with unusual powers. The Ministry of Aviation Industry, for example, even processes its own raw materials and manufactures the individual components to be used in constructing airplanes. A similar solution has been suggested for the computer industry, but has not yet been adopted.

Instead, the Soviet government appears to prefer stop-gap measures to more complex true resolutions of fundamental problems. Reorganizations and directives have not solved problems; many economic and managerial incentives remain counterproductive. The computer industry is still fragmented both geographically (there is some indication of rivalry among the various Republics engaged in computer work) and bureaucratically among competing agencies (mainly ministries, but also the Academy of Sciences). There has been some limited cooperation between

R&D institutes, but their outputs suggest that if they are not actually competitive, they are at least self-isolating. In most instances, links between R&D and production are weak, although the trend has been to send specialists from the R&D institute to the plant to assist in getting a machine into production. The barriers between ministries, on the other hand, appear to have remained rigid.

It is interesting to note that although the German Democratic Republic has a planned economy similar to that of the Soviet Union, the German managerial rewards are different, resulting in better quality output.[2] It is possible that, through their cooperation in the Ryad project, the German Democratic Republic may help to fill in the gaps in the Soviet computer industry on a short-term basis. Such cooperation might be extended indefinitely into the future if the Soviets were to find it in their interest to promote an Eastern European computer industry rather than a Soviet computer industry.

Recent events have indicated that the trend toward internationalizing the Soviet computer industry might very well pay off handsomely. In early 1975, the Control Data Corporation purchased a model of the ES-1040, then the largest machine available in the series, for test and evaluation.[3] The 1040, the largest of the medium-productivity machines to be developed and produced independent of the Soviet Union, was designed by the German Democratic Republic. It has been in production at the Robotron Enterprise in the German Democratic Republic since 1973. Some peripheral equipment for the ES-1040 was produced in other countries. The disks were made in Bulgaria, and the card input-output equipment was made in the USSR. The CDC tests showed that the ES-1040 is indeed compatible with the IBM 360 instruction set. It is also a powerful machine, being "twice as powerful as the IBM 370/145 in scientific/engineering applications, and at least as powerful

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[2] David Granick, *Industrial Management in Four Developed Countries: France, Britain, United States, and Russia* (Cambridge, Mass.: The M.I.T. Press, 1972.

[3] Robert A. Koening, "An Evaluation of the East German RYAD 1040 System," in *American Federation of Information Processing Societies Conference Proceedings*, 1976 National Computer Conference, June 7-10, 1976, New York City, New York (Montavale, New Jersey: AFIPS Press, 1976, pp. 337-340).

in BDP work."[4] The level of technology incorporated in the ES-1040 still lags behind that of U.S. machines: the processor by 3 years, the core memory by about 8 years, and the peripheral equipment by 8 to 10 years. Nevertheless, CDC considers the ES-1040 to be a very reliable machine. The advantages it offers in software compatibility with IBM machines are especially important to the Soviet Union.

In the West, numerous small computer companies have gone out of business or have merged with large companies as they realized they could not compete in the international computer market. Even in Europe, large American-affiliated computer companies dominate the scene. The trend toward larger computer organizations is also apparent in Eastern Europe, but the Soviet Union, which may not be the most qualified nation to do so, is attempting to retain control. Whether the Soviets will ever be willing to relinquish enough control over the evolution of the Eastern European computer industry to realize all of the advantages such an arrangement might allow, remains doubtful.

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[4] Ibid., p. 337.

Appendix

R&D, DESIGN, AND PRODUCTION OF SOVIET COMPUTERS

Models of Soviet computers known to have been put into production are listed in Tables 1, 2, and 3 below. The R&D and design organizations are listed together because (1) they are the same organization (perhaps with various subdivisions undertaking different phases of the work), or (2) the information necessary to distinguish among their contributions to the development of a particular model isn't available. Characteristics of selected Soviet-U.S. computers are shown in Fig. 3 on pp. 133-134.

All major Soviet computer production facilities are controlled by either the Ministry of the Radio Industry or the Ministry of Instrument Construction, Means of Automation, and Control Systems (Minpribor); hence the information has been arranged according to the controlling ministry.

Table 1

MINISTRY OF THE RADIO INDUSTRY: MAJOR COMPUTERS AND PRODUCTION FACILITIES

Model	R&D and Design Organizations and Year Model Completed	Production Facilities and Year Manufacturing Began
ES-1020[a]	Design Bureau of the Minsk Ordzhonikidze Factory and Bulgarian specialists (1971)	Minsk Ordzhonikidze Factory (1971?) and Brest Electromechanical Plant (1972)
ES-1030[a]	Erevan Scientific Research Institute of Mathematical Machines of the Academy of Sciences of the Armenian SSR (1972)	Erevan Elektron Plant (and Poland?)
ES-1050[a]	Design Bureau of the Penza Calculating and Analytical Machines (SAM) Plant?	Penza Calculating and Analytical Machines (SAM) Plant (1973)
ES-1060	Not yet identified	Not yet identified
Minsk-1	Design Bureau of the Minsk Ordzhonikidze Factory (1958-59)	Minsk Ordzhonikidze Factory (1960)
Minsk-2	Design Bureau of the Minsk Ordzhonikidze Factory (1961)	Minsk Ordzhonikidze Factory (1962)

[a]Ryad line.

Table 1--continued

Model	R&D and Design Organizations and Year Model Completed	Production Facilities and Year Manufacturing Began
Minsk-22	Design Bureau of the Minsk Ordzhonikidze Factory (1963)	Minsk Ordzhonikidze Factory (1965)
Minsk-22M	Design Bureau of the Minsk Ordzhonikidze Factory (1965-1966)	Minsk Ordzhonikidze Factory (1966?)
Minsk-23	Design Bureau of the Minsk Ordzhonikidze Factory (1964)	Minsk Ordzhonikidze Factory (1966)
Minsk-32	Design Bureau of the Minsk Ordzhonikidze Factory or Minsk Branch of Scientific Research Center of Computer Technology (1967)	Minsk Ordzhonikidze Factory (1968)
MESM	Computer Center of the Ukrainian Academy of Sciences (1948-1951)	(1951)
BESM-2	Institute of Precise Mechanics and Computer Engineering of the USSR Academy of Sciences and the Computer Center of the Academy of Sciences (1959)	Ul'yanovsk Volodarskii Plant?
BESM-4	Ul'yanovsk Volodarskii Plant and the Institute of Precise Merchanics and Computer Engineering of the USSR Academy of Sciences ("unofficial" transistorized version of the M-20)[b] (1963-1964)	Ul'yanovsk Volodarskii Plant (1964)
BESM-6	Institute of Precise Mechanics and Computer Engineering of the USSR Academy of Sciences and Special Design Office of Moscow Calculating and Analytical Machines (SAM) Plant (1964-1965)	Moscow Calculating and Analytical Machines (SAM) Plant (1966)
M-20	Institute of Precise Mechanics and Computer Engineering and the Special Design Office of the Moscow Calculating and Analytical Machines (SAM) Plant (1957)	Moscow Calculating and Analytical Machines (SAM) Plant (1959); Scientific-Research Institute of Calculating Machine Construction (NIISchetmash), and other facilities of the Ministry of the Radio Industry
M-220	Unknown ("official" transistorized version of the M-20)[b] (1964)	Kazan' (1964)
M-222	Unknown	Kazan'
Strela	Institute of Mechanics and Instrument Design of the Ministry of the Radio Industry? (1953-1954)	Moscow Calculating and Analytical Machines (SAM) Plant? (1953)

[b]For an explanation, see Section IV, pp. 63 and 64.

Table 1--continued

Model	R&D and Design Organizations and Year Model Completed	Production Facilities and Year Manufacturing Began
Strela-3	Institute of Mechanics and Instrument Design of the Ministry of the Radio Industry? (1956)	Moscow Calculating and Analytical Machines (SAM) Plant?
Era	Scientific Research Institute of Calculating Machine Construction (NIISchetmash) of the USSR State Committee on Radioelectronics (1960)	
Ural-1	Institute of Mechanics and Instrument Design of the Ministry of the Radio Industry (1954)	Penza Calculating and Analytical Machines (SAM) Plant (1956)[c]
Ural-2	Product engineering group at the Penza Calculating and Analytical Machines (SAM) Plant (1958)	Penza Calculating and Analytical Machines (SAM) Plant[c]
Ural-4	Product engineering group at the Penza Calculating and Analytical Machines (SAM) Plant (1960)	Penza Calculating and Analytical Machines (SAM) Plant[c]
Ural-11	Product engineering group at the Penza Calculating and Analytical Machines (SAM) Plant (1963)	Penza Electronic Computers (VEM) Plant[c]
Ural-14	Product engineering group at the Penza Calculating and Analytical Machines (SAM) Plant	Penza Electronic Computers (VEM) Plant (1964)[c]
Ural-16	Product engineering group at the Penza Calculating and Analytical Machines (SAM) Plant (1965)	Penza Electronic Computers (VEM) Plant[c]
Razdan-2	Erevan Scientific Research Institute of Mathematical Machines of the Armenian Academy of Sciences (1961)	Erevan Elektron Plant (1962)
Razdan-3	Erevan Scientific Research Institute of Mathematical Machines of the Academy of Sciences of the Armenian SSR (1965)	Erevan Elektron Plant
Nairi-1	Erevan Scientific Research Institute of Mathematical Machines of the Academy of Sciences of the Armenian SSR (1964)	Erevan Elektron Plant (1965)

[c]The explanation for the variation in name could not be determined.

Table 1--continued

Model	R&D and Design Organizations and Year Model Completed	Production Facilities and Year Manufacturing Began
Nairi-2	Erevan Scientific Research Institute of Mathematical Machines of the Academy of Sciences of the Armenian SSR (1966-1967)	Erevan Elektron Plant
Nairi-3	Erevan Scientific Research Institute of Mathematical Machines of the Academy of Sciences of the Armenian SSR (1968-1969)	Erevan Elektron Plant and Baku Radio Factory
Lem-1	Laboratory of Electromodeling (LEM) of the All-Union Institute of Scientific and Technical Information (VINITI) (1955)	
Lem-1-16	Laboratory of Electromodeling (LEM) of the All-Union Institute of Scientific and Technical Information (VINITI) (1957)	-
Lem-1-24	Laboratory of Electromodeling (LEM) of the All-Union Institute of Scientific and Technical Information (VINITI)	
K-200	Elektronika Institute (Kiev)	Pskov Radio Parts Plant (1971)
Elektronika-100	Gorki	

Soviet Computers

Year	Name & Model	MIPS*	Primary Mem Bits	Generation**
1952	BESM - 1	.015	$.08 \times 10^6$	1
1953	Strella - 1	.003	$.08 \times 10^6$	1
1954				
1955	Lem - 1	Unknown		1
1956	Ural - 1	.0001	$.036 \times 10^6$	1
1957				
1958				
1959	Ural - 2	.002	$.08 \times 10^6$	1
	Kiev	.005	?	1
	M - 20	.02	$.18 \times 10^6$	1
1960	BESM - 2	.001	$.08 \times 10^6$	1
	Minsk - 1	.003	$.03 \times 10^6$	1
	Razdan - 1	Unknown		2
	Era	.012	$.16 \times 10^6$	1
1961				
1962	Ural - 4	.005	$.08 \times 10^6$	1
	Minsk - 2	.002	$.3 \times 10^6$	2
	Razdan - 2	.005	$.06 \times 10^6$	2

Equivalent

Equivalent

Equivalent

U.S. Computers

Year	Name & Model	MIPS*	Primary Mem Bits	Generation**
1952	IBM 701	.018	$.144 \times 10^6$	1
1953	UNIVAC 1103	.02	$.5 \times 10^6$	1
1954	IBM 650	.0001	$.08 \times 10^6$	1
1955	IBM 704	.042	1.2×10^6	1
1956	IBM 705	.01	$.3 \times 10^6$	1
1957	ANFSQ7	.09		1
1958	IBM 709	.042	1.2×10^6	1
1959				
1960	CDC - 1604 A	.16	1.5×10^6	2
	IBM 7090	.23	1.2×10^6	2
	UNIVAC Lark	.25	4.6×10^6	2
	IBM 1401	.003	$.1 \times 10^6$	2
1961	Honeywell 800	.084	1.5×10^6	2
	IBM 1410	.014	$.5 \times 10^6$	2
	IBM 7030 (Stretch)	.5	16.8×10^6	2
1962	IBM 7094 I	.25	1×10^6	2
	UNIVAC 1107	.25	2×10^6	2

* MIPS = million instructions per sec

** Generation refers to hardware technology:
1 = Vacuum tubes
2 = Transistors
3 = Integrated circuits
4 = Medium-scale integrated circuits

Fig. 3--Characteristics of selected Soviet-U.S. computers

Soviet Computers

Year	Name & Model	MIPS*	Primary Mem Bits	Generation**
1963	Dnepr - 1	.012	.052 X 10^6	2
	BESM - 3	.02	.44 X 10^6	2
	BESM - 4	.02	.88 X 10^6	2
1964	M - 220	.02	.88 X 10^6	2
1965	Ural - 11	.003	.384 X 10^6	2
	Ural - 14	.01	1.4 X 10^6	2
	Nairi - 1	.002	.036 X 10^6	2
	Minsk - 22	.003	.3 X 10^6	2
1966	BESM - 6	1	1.6 X 10^6	2
	Dnepr - 2	Unknown		2
	Minsk - 23	.003	.24 X 10^6	2
	Nairi - 2	.003	.08 X 10^6	2
1967	Mari	.0003	.048 X 10^6	2
	Kiev - 67	Unknown		2
	Razdan - 3	.03	1.5 X 10^6	2
	Ural - 16	.07	12 X 10^6	2
1968	Nairi - 3	.02	1.5 X 10^6	3
	Minsk - 32	.04	2.5 X 10^6	2
1969	M - 1000	.02	.5 X 10^6	2
	M - 2000	.03	.28 X 10^6	2
	M - 3000	.06	.28 X 10^6	2
1970				
1971				
1972	ES - 1020	.02	2.0 X 10^6	3
	ES - 1030	.01	4.1 X 10^6	3
	M - 4000 †			
	M - 5000 †			
1973	ES - 1050	.50	8.2 X 10^6	3
	M - 4030	.16	1.0 X 10^6	3
	M - 6000	.20	.34 X 10^6	3

U.S. Computers

Year	Name & Model	MIPS*	Primary Mem Bits	Generation**
1963	IBM 7044	.24	1.2 X 10^6	2
	Honeywell 1800	.25	3 X 10^6	2
	CDC 3600	.48	12.6 X 10^6	2
	Philco 212	.67	?	2
1964	IBM 7094 II	.71	1 X 10^6	2
	DEC PDP-6	.25	9 X 10^6	2
	B 5500	.5	1.5 X 10^6	2
1965	GE - 635	.55	38 X 10^6	2
	UNIVAC 1108	1.33	8 X 10^6	3
	IBM 360/20	.02	.12 X 10^6	3
	IBM 360/30	.026	.5 X 10^6	3
1966	CDC 3800	1.0	8 X 10^6	3
	IBM 360/65	.77	8 X 10^6	3
	CDC 6400	1.0	4 X 10^6	3
	CDC 6500	2.0	4 X 10	3
1967	DEC PDP - 10	.5	9 X 10^6	3
	IBM 360/91	7.8	8 X 10^6	3
1968	IBM 360/95	9.7	.25 X 10^6	3
1969	B - 6500	2.5	5 X 10^6	3
	IBM 360/85	4.4	.25 X 10^6	3
	CDC - 7600	15	40 X 10^6	3
1970				
1971				
1972	Illiac - IV	128	8.7 X 10^6	4
1973	CDC Star	50	64 X 10^6	4

Fig. 3--*continued*

* MIPS = million instructions per sec

** Generation refers to hardware technology:
1 = Vacuum tubes
2 = Transistors
3 = Integrated circuits
4 = Medium-scale integrated circuits

† Technical data not generally available.

Table 2

MINISTRY OF INSTRUMENT CONSTRUCTION, MEANS OF AUTOMATION, AND CONTROL SYSTEMS (MINPRIBOR): MAJOR COMPUTERS AND PRODUCTION FACILITIES

Model	R&D and Design Organization and Year Model Completed	Production Facilities and Year Manufacturing Began
M-1000[a]	Tbilisi Scientific Research Institute Institute of Instrument Construction and Means of Automation, and other, unnamed institutes under Minpribor	Tbilisi Experimental Plant of Control Computers and the Experimental Plant of the Tbilisi Scientific Research Institute of Instrument Construction and Means of Automation (1969)
M-1010[a]	Not yet identified	Not yet identified
M-2000[a]	Severodonetsk Scientific Research Institute of Control Computers	Kiev Electronic Computer and Control Machines (VUM) Plant? (1969)
M-3000[a]	Severodonetsk Scientific Research Institute of Control Computers	Kiev Electronic Computer and Control Machines (VUM) Plant? (1969)
M-40[b]	Not yet identified	Not yet identified
M-400[b]	Not yet identified	Not yet identified
M-4000[b]	Institute of Cybernetics of the Ukrainian SSR Academy of Sciences?	Kiev Electronic Computer and Control Machines (VUM) Plant (1972?)
M-4030[b]	Not yet identified	Not yet identified (1973)
M-5000[b]	Special Design Bureau of the Sigma Association?	Vilnius Calculating Machines Plant (1972)
M-6000[b]	Not yet identified	Not yet identified (1973)
Kiev	Computer Center of the Academy of Sciences of the Ukrainian SSR[c] (1959)	
Kiev-67	Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR[c] (1967)	

[a]ASVT-D (Modular System of Computer Hardware--discrete elements) line.

[b]ASVT-M (Modular System of Computer Hardware--microelectronics) line.

[c]Since 1962, the Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR.

Table 2--continued

Model	R&D and Design Organization and Year Model Completed	Production Facilities and Year Manufacturing Began
Mir-1	Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR[c] (1964)	Kiev Electronic Computer and Control Machines (VUM) Plant (1966?)
Mir-2	Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR[c] (1969)	Kiev Electronic Computer and Control Machines (VUM) Plant
Dnepr-1[d]	Computer Center of the Academy of Sciences of the Ukrainian SSR (1961)[c]	Kiev Electronic Computer and Control Machines (VUM) Plant (1963)
Dnepr-2	Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR (1965-1966)	Kiev Electronic Computer and Control Machines (VUM) Plant
Dnepr-21	Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR	Kiev Electronic Computer and Control Machines (VUM) Plant
Dnepr-22	Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR	Kiev Electronic Computer and Control Machines (VUM) Plant
Promin'	Computer Center of the Ukrainian Academy of Sciences of the Ukrainian SSR[c] (1962)	Unknown (1965)
Promin'-M	Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR (1967)	Severodonetsk Instrument Construction Plant (1967)
Promin'-2	Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR (1967)	Severodonetsk Instrument Construction Plant?
UM-1-NKh	Ministry of the Electronics Industry and the Ministry of Instrument Construction, Means of Automation, and Control Systems (Minpribor)	Leningrad Electromechanical Plant (1967)
MPPI-1	Severodonetsk Scientific Research Institute of Control Computers (1962-1963)	Severodonetsk Computer Factory?
UM-1	Severodonetsk Scientific Research Institute of Control Computers (1963)	Severodonetsk Instrument Construction Plant (1968)

[d]Also called the Dnipro (Ukrainian equivalent) and the UMShN.

Table 2--continued

Model	R&D and Design Organization and Year Model Completed	Production Facilities and Year Manufacturing Began
KVM-1	Severodonetsk Scientific Research Institute of Control Computers (date unknown)	(1965)
Kashtan	Kiev Electronic Computer and Control Machines (VUM) Plant	Kiev Electronic Computer and Control Machines (VUM) Plant (1972?)
Ruta-110	Sigma Association of Calculating and Organizational Equipment Enterprises (1964-1965)	Vilnius Calculating Machines Plant (1965-1966)
ATE-80	Scientific Research Institute of Calculating Machines (NIISchetmash)	Vilnius Calculating Machines Plant (1967)
Tbilisi-1	Tbilisi Scientific Research Institute of Instrument Construction and Means of Automation (1967)	Experimental Plant of the Tbilisi Scientific Research Institute of Instrument Construction and Means of Automation
Gelati-3	Tbilisi Scientific Research Institute of Instrument Construction and Means of Automation (1968)	Tbilisi Experimental Plant of Control Computers (1972?)
Gelati-5	Tbilisi Scientific Research Institute of Instrument Construction and Means of Automation (1970)	Tbilisi Experimental Plant of Control Computers (1972?)
Ros'	Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR	Tochelektropribor Enterprise (Kiev Precision Electrical Appliances Factory) (1970)
Sever'-2		Tomsk Mathematical Machines Plant
Iskra[e]	Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR and the Kursk Calculating Machines ("Schetmash") Factory	Kursk Calculating Machines ("Schetmash") Factory
Iskra-11[e]	Moscow and Leningrad engineers?	Orlov Control Computer Plant (1970)
Iskra-11M[e]	Moscow and Leningrad engineers?	Orlov Control Computers Plant

[e]Electronic keyboard calculators.

Table 2--continued

Model	R&D and Design Organization and Year Model Completed	Production Facilities and Year Manufacturing Began
Iskra-111[e]	Moscow and Leningrad engineers?	Orlov Control Computers Plant (1971)
Iskra-110[e]		Smolensk Small Computer Plant (1972) and Penza Electronics Computers (VEM) Plant (1972)
Iskra-12[e]	Moscow and Leningrad engineers	Kursk Calculating Machines ("Schetmash") Factory and Orlov Control Computers Plant
Iskra-12M[e]	Kursk Calculating Machines ("Schetmash") Factory (1971?)	Kursk Calculating Machines ("Schetmash") Factory (1971?)
Iskra-122[e]	Leningrad engineers and Design Bureau of the Kursk Calculating Machines ("Schetmash") Factory	Kursk Calculating Machines ("Schetmash") Factory (1972)
Iskra-22[e]	Leningrad engineers and Design Bureau of the Kursk Calculating Machines ("Schetmash") Factory?	Kursk Calculating Machines ("Schetmash") Factory
Iskra-112P[e]	Kursk Calculating Machines ("Schetmash") Factory (1971?)	Kursk Calculating Machines ("Schetmash") Factory (1972?)
Iskra-23[e]	Ryazan' Calculating-Analytical Machines Plant	Ryazan' Calculating-Analytical Machines Plant

[e]Electronic keyboard calculators.

Table 3

UNASSIGNED COMPUTERS

Model	R&D and Design Organization and Year Model Completed	Production Facilities and Year Manufacturing Began
M-2	Institute of Electronic Control Computers of the USSR Academy of Sciences (1953)	
M-3	Institute of Electronic Control Computers of the USSR Academy of Sciences (1957-1959)	
VNIIEM-1[a]	All-Union Scientific Research Institute of Electromechanics (VNIIEM) of the Ministry of Electronics Industry (1962-1963)	
VNIIEM-3[a]	All-Union Scientific Research Institute of Electromechanics (VNIIEM) of the Ministry of Electronics Industry (1966)	
Setun'	Moscow University	Unidentified plant of the Middle Volga Sovnarkhoz (1965)

[a]See the discussion on "Planning and Management of R&D and Production" in Section II, p. 10, for details.

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[1] Inconsistencies in the transliteration of Russian words in this report occur because the author preferred the widely used Library of Congress transliteration system, whereas other sources have used the U.S. Board of Geographic Names system.

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